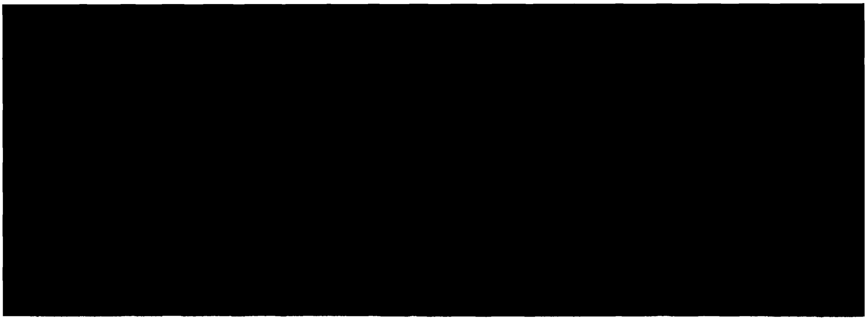
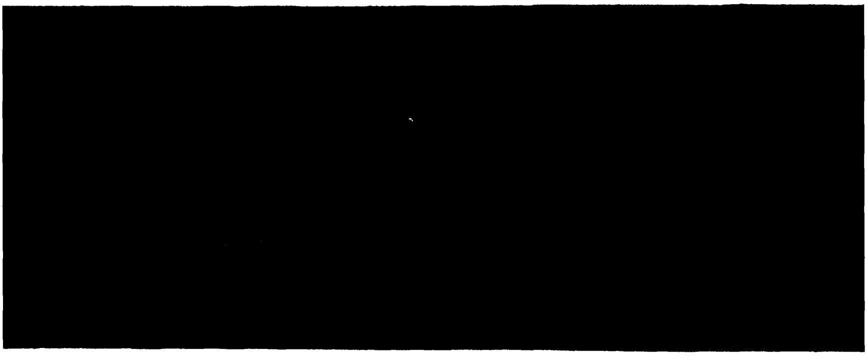
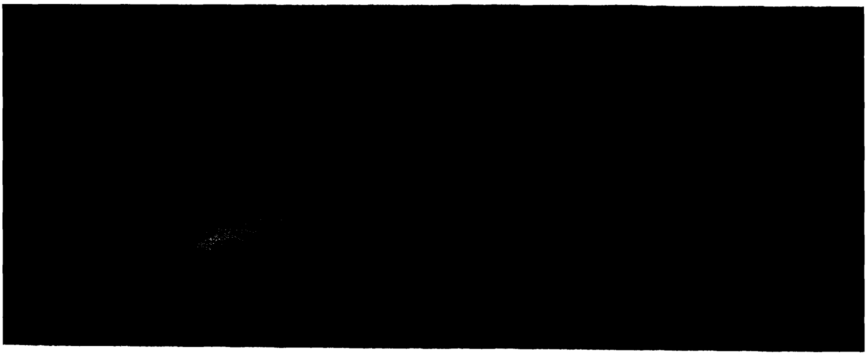


Oxyhydrogen NEUTRAL flame: Neutral flame is used for all welding. Volume of hydrogen should be approximately twice that of oxygen.



Oxyhydrogen OXIDIZING flame: Oxidizing flame is harmful in all cases; shows excess oxygen. Adjust valves for more hydrogen or less oxygen to balance mixture.

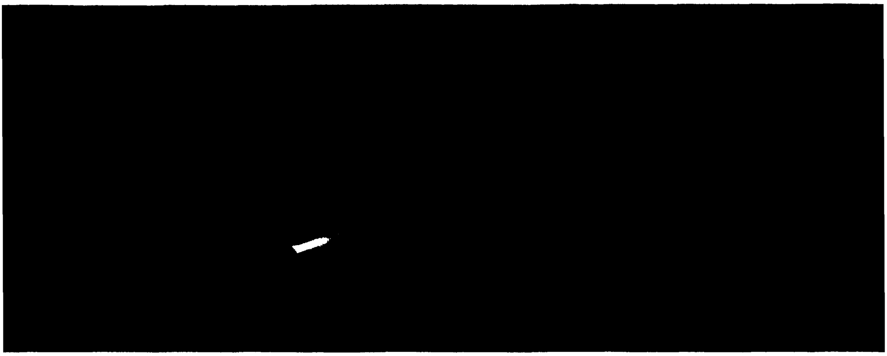


Oxyhydrogen REDUCING flame: Reducing flame is low-temperature flame; used for torch brazing, but is not suitable for welding. For neutral welding flame adjust valves to increase oxygen or decrease hydrogen.

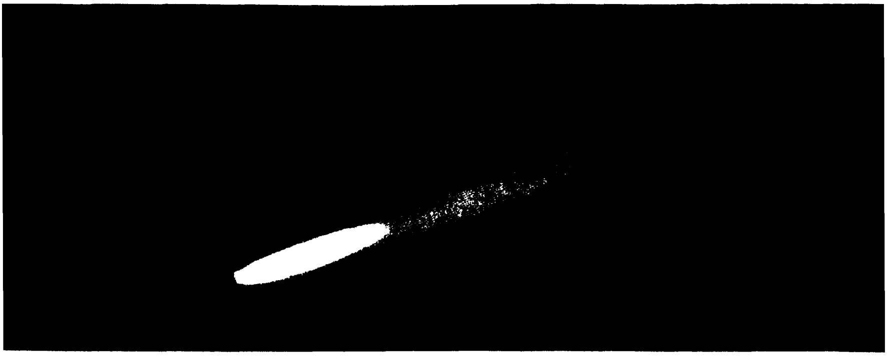
FLAME ADJUSTMENT FOR TORCH

Remove goggles and clean torch tip before adjusting flame.

Oxyacetylene NEUTRAL flame: Neutral flame is used for all welding. Volumes of acetylene and oxygen are approximately equal.



Oxyacetylene OXIDIZING flame: Oxidizing flame is harmful in all cases; shows excess oxygen. Adjust valves to increase acetylene or decrease oxygen.



Oxyacetylene REDUCING flame: Reducing flame is low-temperature flame; used for torch brazing, or when adjusted to be only slightly reducing, for welding. For neutral welding flame, increase oxygen or decrease acetylene.

WELDING AND BRAZING ALUMINUM

Courtesy of: Aluminum Company of America

MODERN WELDING PRACTICE

By

ANDREW D. ALTHOUSE, B.S., M.A.
SUPERVISOR OF VOCATIONAL EDUCATION
Detroit Public Schools
Member of American Welding Society

and

CARL H. TURNQUIST, B.S., M.S.
HEAD OF AUTOMOTIVE, AERONAUTICAL, REFRIGERATION AND WELDING DEPARTMENTS
Cass Technical High School
Detroit
Associate Member of American Welding Society

With the Collaboration of

GEORGE E. TABRAHAM, B.S., M.A.
PRINCIPAL AEROMECHANICS HIGH SCHOOL
Detroit

and

BURL E. OTT, B.S., M.A.
Retired
FORMER HEAD OF AUTOMOTIVE, AERONAUTICAL AND WELDING DEPARTMENTS
Cass Technical High School
Detroit

Second Edition

CHICAGO
THE GOODHEART-WILLCOX COMPANY, INC.
Publishers
1953

Printed in the United States of America

PREFACE

Since this book was first published in 1942, we have seen the development of many new welding machines and processes. Accordingly a new chapter XIX has been allocated to modern welding processes and materials.

Recently the American Welding Society brought out a new Qualification Procedure which made the earlier procedures obsolete. These new procedures are carried in this edition.

As in the first edition emphasis has been placed on the proper techniques in welding in order that the beginner may understand and practice correct welding procedures. Safety is likewise again stressed in this new edition.

With the increase in rural electrification and the increased use of machinery on the farm, welding in the farm shop has become a basic farm shop process. This trend is recognized in this edition with the addition of a section on farm shop welding.

To be a successful welder the operator must have a good basic understanding of the properties and characteristics of metals. Although this subject was covered in some detail in the first edition it has been expanded considerably in this second edition.

The extensive use of the first edition indicated that the book was often purchased as a reference book on welding. The second edition attempts through the addition of information on many new types of welding and welding materials, to make the book much more valuable for reference purposes.

As was the case in the first edition the authors were again given cooperation and assistance by the various manufacturers and welding supply companies in their furnishing valuable illustrations, material and checking certain technical information and data.

We wish particularly to recognize the assistance given us by the following companies and organizations:

Air Filter Corporation
Air Reduction Sales Company
Ajax Electrothermic Corporation
Allis-Chalmers Mfg. Company
Aluminum Company of America
American Iron and Steel Institute
American Welding Society
Anzick Manufacturing Company
Arcos Corporation
Bausch and Lomb Optical Company
Borm Manufacturing Company
Bernard Welding Equipment Company
Buffalo Forge Company
Champion Rivet Company
Cincinnati Electric Tool Company
Clayton and Lambert Mfg. Company
Cleveland Crankshaft Company
Continental Industrial Engineers
Craftsweld Equipment Corporation
Delta Manufacturing Division, Rockwell Mfg. Company

Detroit Testing Machine Company
Dockson Corporation
D V Welding Controls
Eisler Engineering Company, Incorporated
Electric Controller and Mfg. Company
Electric Storage Battery Company
Erico Products, Incorporated
Federal Machine and Welder Company
Foster Transformer Company
Fusion Engineering
The Gasflux Company
General Electric Company
General Electric X-Ray Company
General Motors Corporation
Handy & Harman
Harnischfeger Corporation
Harris Calorific Company
Hobart Brothers Company
Imperial Brass Mfg. Company
Jackson Products
Lincoln Electric Company
Linde Air Products Company
Magnaflux Corporation
Magnetrode Corporation
Mallory, P. R., and Co., Incorporated
Metal and Thermit Corporation
National Carbon Company Incorporated
National Cylinder Gas Company
National Electric Welding Machines Company
Nelson Stud Division of Morton Gregory Corporation
Norton Company
Petersen Manufacturing Company
Pier Equipment Mfg. Company
Progressive Welder Company
Shore Instrument and Mfg. Company
Taylor-Winfield Corporation
Tempilo Corporation
Thermacote Company
Tinius Olsen Testing Machine Company
Torchweld Equipment Company
Tru-Line Corporation
Tube Turns, Incorporated
U. S. Steel Corporation
Victor Equipment Company
Walker Turner Company, Incorporated
Wall-Colmonoy Corporation
Welding Equipment & Supply Company
Weldit Acetylene Company
Westinghouse Electric and Mfg. Company
William Dixon, Incorporated
Wilson Mechanical Instrument Co., Incoporated

ANDREW D. ALTHOUSE
CARL H. TURNQUIST

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CHAPTER I

OXY-ACETYLENE WELDING THEORY AND PRACTICE

The history of the development of acetylene and arc welding is interwoven with the industrial and economic history of our country. It is the history of a search for a better way. The development of the automobile and some of the problems of automotive service demanded a quick and convenient method of heating parts, particularly for repairing and straightening parts which had been injured in service. The old type of forge welding did not readily lend itself to this type of work.

With the demand on the part of many industries for a still more rapid and more nearly automatic type of welding, there was developed electric welding of various types; with the development of the airplane, new uses for welding came into existence. Welding is now one of the most important of the metal working processes.

Thru the development of the art of welding we now have all-steel bodies for automobiles, metal trains, bridges, buildings, boats, and innumerable other articles of all metal welded construction.

1. History of Welding

It is interesting to learn when welding started, how rapidly it developed, and in what forms it appeared through its various stages of development.

The first important method of welding metals together was by the forge method, which dates back to the 13th century in Moyeure in the Lorraine District. The bellows on these early forges were operated by water power.

Nearly everything with which the blacksmith worked, including many of the tools of other trades, were handmade by him, with the exception of the iron itself.

The forge and chimney were usually built of brick; large bellows were also used to supply air for the blast. This was usually made of wood construction for the frame-work and covered with leather attached by means of brass nails. This bellows was suspended from a heavy wooden rack. The bellows was used to pump air into the forge, thus making an under draught for the charcoal fuel to heat the iron which was to be welded. The bellows was sometimes called a "leather lung."

The bellows was usually about 4 to 6 feet long. The main part swelled out to a large width of pleated leather. When in operation, the upper and lower parts were pushed far apart, extending the bellows to a height of two or more feet.

The bellows was connected to the forge by a small pipe, and the large end of the bellows was impelled by a long pole fastened at its center, extending from the bellows to the smith at the forge. This was attached to the lower part of the bellows by means of a chain and hook.

The fire in a forge is usually fed with soft, or bituminous coal, which is a form of impure carbon, although charcoal is sometimes used. The coal should be nearly free from sulphur and phosporus as these elements may be absorbed by the iron and cause a harmful effect.

Good welding with a forge and anvil requires considerable experience. The iron must be brought to a white heat without burning. The temperature is controlled by the air blast from the bellows. The pieces to be welded are then placed together on the anvil and pounded together forming one piece.

The metal to be welded must have coals under it in order that most of the oxygen from the blast will have been consumed before the gases reach the iron which is being heated. Otherwise the iron will become burned, or oxidized, and a poor weld will result.

The history of oxygen-acetylene welding dates back many years and reflects the efforts of many physicists, scientists, engineers, and industrialists to develop some other easier means to fabricate structures out of metals. From these scientific researches, many welding processes were devised. Of the methods developed, the oxygen-acetylene and the various electrical methods have come to be the most prominent.

The development of the oxygen-acetylene welding method dates back to the turn of the century (1901-1903), when the first successful oxygen-acetylene welding equipment was developed in Paris, France, by Edmond Fouché in collaboration with Picard. These men introduced the equipment to the commercial industries a year later, and it proved successful from the start.

The acetylene and oxygen gases used in the oxy-acetylene welding process were discovered many years before the development of the oxygen-acetylene torch. See Chapter 19 for the chemistry of welding.

Acetylene was first discovered in 1836. It was not produced successfully on a commercial basis until many years after this, when

the use of calcium carbide was first discovered. The Woolsen Allen Company, located in North Carolina, was the first company to produce commercial acetylene (1892). It was used as a gas for lighting.

Oxygen was discovered many centuries ago, but the preparation of it on a commercial basis was not started until 1892. At this time the method of liquefying air (Parkinson) provided economical production of it. The electrolysis method of breaking water down into oxygen and hydrogen gases was discovered in 1800 by the scientists Nicholson and Carlisle, but has not been used to a great extent commercially, except in localities where hydrogen is needed for industrial purposes.

Before the oxygen-acetylene torch was finally developed, many other gases were tried in a search for a suitable heating flame; and many attempts to use combustible substances and air were tried and discarded. In 1888, Fletcher made some welding equipment in England using oxygen and coal gases, but the oxygen-acetylene torch was produced in France by Fouché and Picard.

Several men who had been working along the same lines in the United States produced commercially successful torches in 1903. In 1903, Charles L. Bastian invented the diaphragm type regulator, which made a constant gas pressure to the torch possible. The first torches were crude, but their development has progressed rapidly since their introduction so that today we have several types of torches used for many different kinds of oxygen-acetylene welding.

A cutting torch, which means an especially adapted welding torch used for the cutting of metals, was first introduced to the industry by Felix Jottrand of Brussels, Belgium, 1905. This proved a success from the start. Jottrand obtained his oxygen by the electrolysis of water, a method which produces very pure oxygen.

The welding industry grew very rapidly, and by the year 1907 the use of oxygen-acetylene equipment was very popular in all parts of Europe, especially in England. In the United States, the development was somewhat slower because of the difficulty of obtaining oxygen. Most of the oxygen obtained was derived from heating potassium chlorate or manganese dioxide. Acetylene was plentiful, being obtained from calcium carbide. In 1907, the first liquid oxygen plant was built in the United States using European-built equipment. The method followed in the plant was to liquefy air and to remove the oxygen from the air by boiling it out at a low temperature. See Chapter 2 for an extensive explanation of this process.

Oxygen-acetylene equipment is not used extensively in automatic

machines, but its development for job welding has been very rapid since 1907. Today we have oxygen-acetylene welding torches in a multitude of different sizes and shapes for different kinds of welding. We also have cutting torches either hand-operated, or built into an automatic machine which controls the pattern which the torch is to cut. Cutting torches have been developed to the point where they can cut metals and leave a very smooth surface. At the present, besides the use of the oxygen-acetylene torch, oxygen and hydrogen are used to weld low melting temperature metals where a high degree of purity is desired, while artificial and natural gases are used with oxygen to braze, solder, and weld low melting temperature material such as lead, etc. For instance, in the jewelry industry, city gas (or natural gas and air) are used for such work as silver soldering, etc. Other gases such as Blau gas, Hydro-carbon (Pintsch Gas), thermaline, pentane, butane, etc., have been tried with oxygen, but the oxy-acetylene combination is still the most popular because of the fact that a higher temperature is obtainable, and the products of combustion are harmless.

2. Definition of Welding

Welding is the term applied to the autogenous fusion of metals. By autogenous welding is meant the fusion of two like metals together, or the melting of two similar metals so that the outer portions may mix. This, when followed by cooling, fuses them together. When two metals are connected by means of another metal, the process is called soldering. For example, welding may be described as the fusion of two pieces of steel together, of two pieces of copper together, or of two pieces of lead together. Soldering is the fastening of two pieces of steel together using brass (commonly called brazing), the fastening of copper and a piece of steel together using a lead and tin alloy, or the fastening of a piece of steel and copper together by using silver.

Welding may be defined as an art. The skill to weld and solder metals together can only be obtained after a diligent study of the methods and a period of careful and correct practice. In classifying it as an art, it is meant that some persons can do welding better than others because of a seemingly natural gift, although it has been found that any normal person can under good instruction and by following the correct methods in time become a successful welder. By saying that welding is an art, it is further meant that continuous practice is necessary in order to maintain a high standard of skill in this kind of work. It is, therefore, recommended that only cor-

rect equipment be used when learning welding, that only good metals be used to practice on, that a thorough, fundamental procedure be undertaken, and that very careful supervision be given the student during the first practice session in order to correct early mistakes.

3. Different Types of Welding and Cutting

The common types of welding are: Oxygen-acetylene welding, electric metallic arc welding, electric resistance welding, carbon arc welding, atomic-hydrogen welding, thermit welding, the induction furnace, the hydrogen furnace, oxygen-acetylene cutting, carbon arc cutting, and automatic welding of all types.

4. Welding Flames

Gas welding is the art of joining or fabricating various metals together by melting and fusing them. It consists of applying a very intense concentrated flame on a metal to the end that the spot

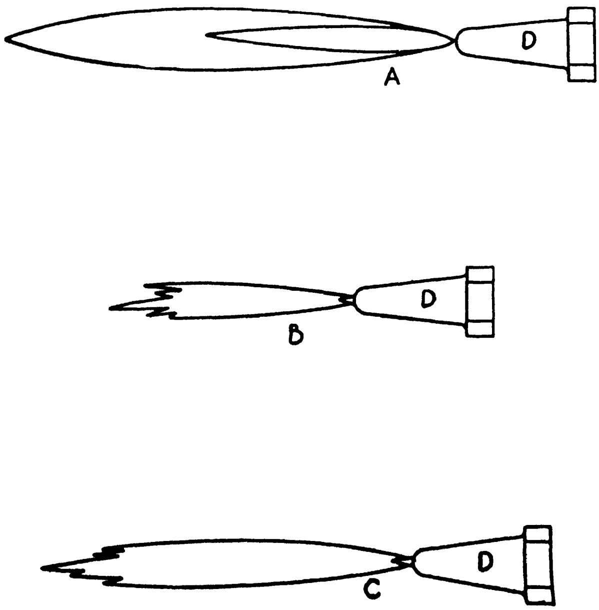


Figure 1. Welding Flames: A. Carburizing flame, B. Oxidizing flame, C. Neutral flame, D. Torch tip

becomes molten and forms a puddle. When two metals puddle, the edges of the two pieces are one. This process must be performed in a manner that does not permanently injure the metals which are

being melted and, therefore, a welding flame must have the following qualities:

A. The flame must be of high enough temperature to melt the metals.

B. Sufficient heat must be supplied to overcome heat losses.

C. The flame must not burn the metal. (Oxidize it.)

D. The flame must not add dirt or foreign material to the metal.

E. The flame must not add carbon to the metal.

The quantity of heat is determined by the amount (cu. ft. per hour) of gases burned. To obtain more heat, the tip orifice is made larger and more pressure is supplied to feed the gas faster to the tip. Whether a large torch or a small torch is used, the temperature of the oxy-acetylene flame is always approximately 6300° F.

A. The elimination of oxidizing and carbonizing flames is determined by the proportions of the two gases mixed. If too much oxygen is used, an *oxidizing flame* results; while if too much acetylene is used, a *carbonizing flame* results. These two flames are easily recognized as explained in Paragraph 7. The correct flame, which heats the metal and does not carbonize or oxidize it, is called a *neutral flame.* This latter flame is the result of a perfect proportion and mixture of acetylene and oxygen. *Figure 1.* In a neutral flame, these two gases unite with the effect that the oxygen burns up the carbon and the hydrogen in the acetylene, and releases only heat and harmless gases.

B. (Refer to Chapter 19 for a description of the chemistry of the welding flame.)

In chemical terms, acetylene + oxygen = carbon dioxide + water (steam) + heat.

The two gases formed, CO_2 (carbon dioxide) and H_2O (water in the vapor form), are perfectly harmless. The oxygen in the air surrounding the flame is used to complete the burning. This means that in crevices and corners where the air has difficulty in getting to the flame, additional cylinder oxygen must be fed to the flame by the torch.

The effect of a poor mixture of gases in the welding flame is easily recognized, and the final test for a neutral flame is determined by the manner in which the metal reacts to melting under the flame. See Paragraph 9.

Dirt in a welding flame may come from two sources:

A. Poor gases.

B. Dirty equipment.

Poor and cheap gases should never be used. The purity of the

gases made by the manufacturers should be noted and taken into consideration. A neutral welding flame will produce a temperature of approximately 6300° F. A table of temperatures required to melt the various metals is listed in *Figure 2.* It may be noticed from this table that the temperature of the oxy-acetylene flame is sufficiently high to melt practically every metal.

Metal	Melting Temperature Degrees Fahrenheit
Aluminum	1215
Brass (yellow)	1640
Bronze (cast)	1650
Copper	1920
Iron, Gray cast	2200
Lead	620
Steel (.20%)	2800
Solder (50-50)	420
Tin	450
Zinc	785

Figure 2. Welding temperatures (fusion) for various common metals

5. Oxygen Acetylene Welding Equipment

Before the welding procedure may be discussed, it is necessary that the equipment which is used should be thoroughly understood in order that its limitations and its possibilities may be kept in mind when learning the welding processes.

Basically, welding equipment consists of a source of supply of two gases, oxygen and acetylene, and a mechanism whereby the gases are supplied to a tip, at which point they are mixed and ignited and a high temperature flame produced. In the order of progression of the gases through the equipment, the following apparatus will be found in common usage. *Figure 3.*

a. Gas cylinders
   1. oxygen cylinder
   2. acetylene cylinder

b. Pressure regulators
   1. oxygen regulator
   2. acetylene regulator

c. Pressure gauges
   1. high pressure gauges
      a. oxygen gauge
      b. acetylene gauge
   2. low pressure gauges
      a. oxygen gauge
      b. acetylene gauge

d. Hose
   1. oxygen hose
   2. acetylene hose

e. Welding torch
   1. valves
   2. body
   3. mixing chamber
   4. tip

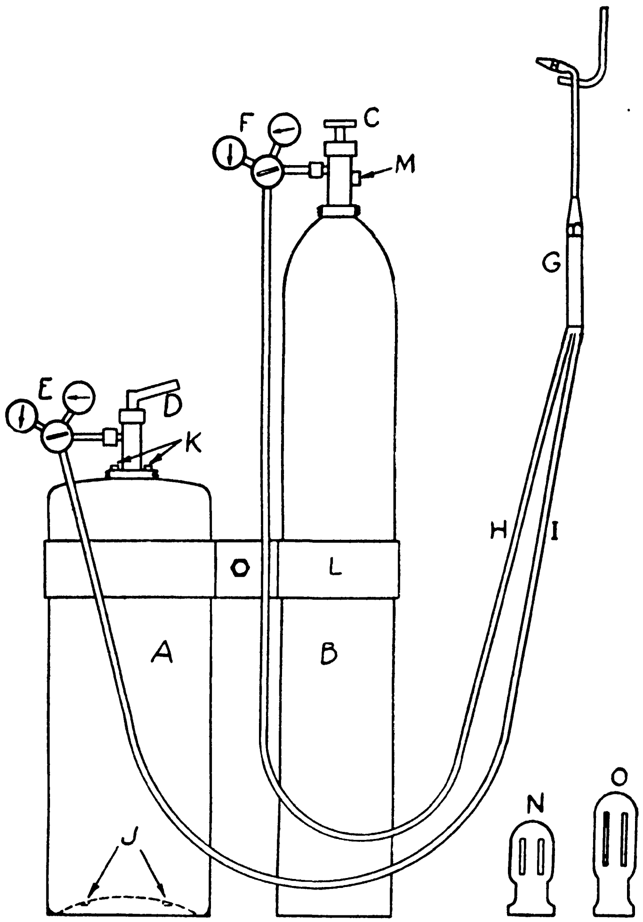


Figure 3. Oxygen-Acetylene Welding Equipment: A. Acetylene cylinder, B. Oxygen cylinder, C. Oxygen cylinder valve, D. Acetylene cylinder valve, E. Acetylene regulator and gauges, F. Oxygen regulator and gauges, G. Torch, H. Oxygen hose, I. Acetylene hose, J & K. Acetylene fuse plugs, L. Cylinder support, M. Oxygen safety plug, N. Acetylene cylinder valve cap, O. Oxygen cylinder valve cap

6. Assembling the Welding Equipment

The proper use in handling the welding equipment is absolutely essential to obtain good welding and to obtain a reasonable length of service of the equipment. The oxygen and acetylene cylinders are owned by the companies which furnish the gases contained in the cylinders. A small rental, or demurrage, is charged for the use of the cylinders after a certain free rental interval. The remainder of the equipment, however, is usually the property of the

operator. Reasonable care should be exercised in the use of all this equipment to keep it in good condition.

The excessive pressures in the oxygen cylinder, and the ease of combustion of the acetylene make it necessary that great care be used when handling cylinders. See paragraph 25 for further information on handling cylinders. Always wear recommended goggles when welding. See paragraph 39 for specifications of welding goggles.

Starting up and shutting down the equipment is the same regardless of the different operations. The recommended safety practice must always be followed when working with welding equipment.

Before welding equipment may be used, it is very important that the equipment be properly assembled. The first thing to be noticed is whether the gas cylinders are in proper condition. These cylinders should be fastened so securely that there is no chance of upsetting or of abusing them in any manner. If the apparatus is portable, these cylinders should be fastened to the truck by means of steel straps or chains; and the truck should be so designed that it is almost impossible to upset it accidentally. For stationary equipment, the cylinders should be fastened to the walls, floors, or posts, by means of chains or steel straps. These safety devices must be of a convenient design to make possible the quick change of cylinders when the gas supply is depleted. Before attaching the regulators to the cylinders, the cylinder openings should be blown out by opening the cylinder valve slightly (cracking) and allowing some of the high pressure gas to blow through the valve openings to remove any dirt particles. The regulators may now be attached to the cylinder. Only fixed end wrenches, having wide jaws, should be used on these fittings to prevent injuring them. Be sure that the regulator fits the tank fitting. A variety of types of tank and regulator fittings are in use. See paragraph 26 for a list of common tank fittings. The hose running from the regulators to the torch should be fastened firmly to the respective fittings, and should be installed in a manner that does not leave the hose twisted when the torch is held in the welding position. The torch when held in a welding position should not strain the operator's hand, or make it necessary for the operator to twist the torch to get it in place. Also, the two hoses should not be twisted one around the other. Before fastening the hose to the torch, the hose lengths should be blown out by opening the tank valves and screwing in the regulator screws, allowing acetylene, or oxygen to escape

through their respective hoses. The pipe threads are sealed with pipe thread-sealing compound (glycerine and litharge paste is recommended) when assembled. After the equipment has been assembled, it should be tested with soap suds for leaks, as a leak anywhere in the system would be uneconomical and might be dangerous.

Following this, the torch should be attached to the hose. Note that on most oxy-acetylene welding equipment, the hose nipples have left hand threads on the acetylene hose fittings, and right hand threads on the oxygen hose fittings. With the welding equipment assembled as described above, next test for leaks.

Leak testing is very essential and should never be neglected when installing any new cylinder or any part of the apparatus.

To test for leaks, the only recommended procedure is to put *soap suds* on the outside of the joints suspected of leaking. Oil or flames of any kind should never be used. To test for leaks, one should turn the cylinder valve on, and build up from 15 to 25 pounds of pressure in the regulator and hose. Then apply the soap suds solution to the joints; and bubbles will indicate any leaks.

When first using welding equipment, the main problems are: to learn the proper methods of igniting the torch, to adjust it for the proper flames, and to learn the proper method of shutting down the equipment.

The handling of the torch and the various tips used is dependent upon the type of weld desired, the kind of metal used, and the structure (shape and position) of the metal in general. These problems must be taken up individually and are included in the following chapters.

7. Lighting the Torch

The problem of lighting the torch consists of turning on the gases, and adjusting them to the proper pressures for the particular task on hand. The following procedure is for high and medium pressure systems, sometimes called the balanced pressure type.

The steps in general are as follows:

1. Check the equipment to make sure the apparatus is in good condition.
2. Inspect the regulators (the adjusting screws of the regulators should be turned all the way out).
3. Open the oxygen cylinder *very slowly* until the high pressure gauge shows its maximum rating, and then turn the valve all the way out. (The operator should not stand in front of the gauges while doing this.) The reason for turning the oxygen

tank valve all the way out is that this valve has a double seat. In all the way out position, this seat closes any possible opening through which oxygen may escape along the valve stem.

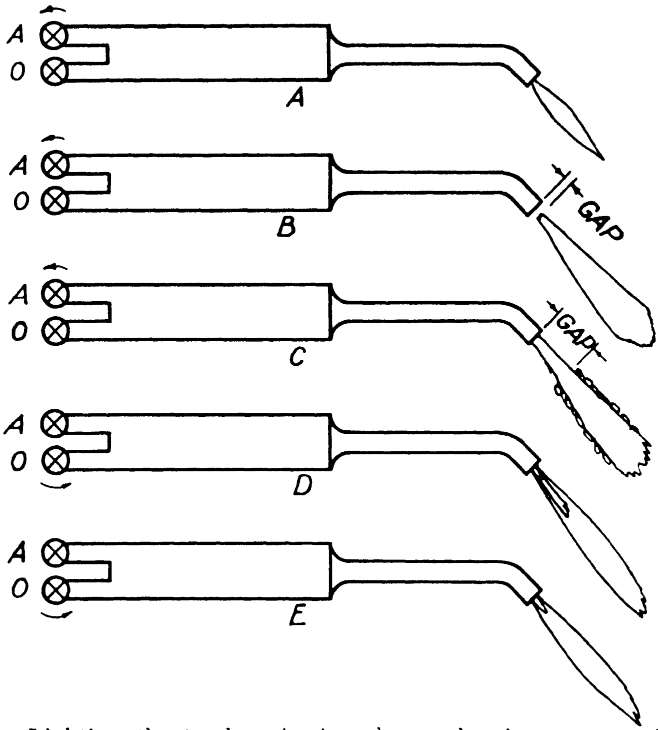


Figure 4. Lighting the torch: A. Acetylene valve just open and a small acetylene flame, B. Acetylene valve opened until acetylene will jump away from and back to tip, C. Alternate method of adjusting for the combustion of acetylene, turbulence must be about ¾" to 1" away, D. Oxygen being slowly turned on, E. Oxygen turned on until neutral flame is obtained

4. Open the acetylene cylinder valve *slowly,* using only the proper sized wrench. Never open it more than ¼ to ½ turns. Always leave the wrench in place on the cylinder valve in order that the cylinder may be shut off quickly in case of an emergency.

5. Open the oxygen valve of the torch one turn. Now turn the oxygen-regulator, adjusting screw in, until the low pressure oxygen gauge indicates the pressure corresponding to the tip number. Then turn off the oxygen valve on the torch. This procedure is to adjust the oxygen torch pressure. (A No. 4 tip should have 4 lbs. per sq. inch.)

6. Open the acetylene torch valve one turn. Turn the acetylene regulator adjusting screw in slowly until the low pressure acetylene gauge indicates the pressure corresponding to the tip

size. Then turn off the acetylene torch valve. (A No. 4 tip should have 4 lbs. per sq. inch.)

7. The torch pressures have now been adjusted to approximately the proper pressure. All the valves are in a position to feed the gases to the torch.

8. Open the acetylene torch valve $\frac{1}{16}$ to $\frac{1}{4}$ of a turn. Light the acetylene now coming out of the tip. The recommended methods of igniting this acetylene may be found in Paragraph 40.

9. Now turn the acetylene torch valve on slowly until the acetylene flame jumps away from the end of the tip slightly. This indicates that the proper amount of acetylene is being fed to the tip. One should be able to make the acetylene leap away from the tip $\frac{1}{16}''$ and back again to the tip by the motion of one's hand. If the acetylene will not jump back to the tip, it means that too much acetylene has been turned on. If it is a used tip, one will sometimes find it difficult to make the acetylene jump away from the tip. To eliminate this trouble, the operator will have to try to force the acetylene from the tip by a wave of his hand. *Figure 4.*

Another method of adjusting for the correct amount of acetylene is to increase the flow until the flame becomes turbulent (rough) a distance of 1″ to 1½″ from the tip of the torch. Also the operator will note that when sufficient acetylene has been turned on, the flame will stop smoking, or releasing soot.

10. After the proper amount of acetylene has been obtained, the oxygen valve on the torch is opened slowly. As the oxygen is fed into the acetylene, the brilliant acetylene flame turns a purple tinge and a small inner cone starts to form. This inner cone is of a light greenish color and when first formed, the extremity of it will have a blurred and irregular contour. But as the oxygen is turned on slowly, the inner cone finally loses its blurred edge and becomes a round, smooth cone. When this occurs, do not turn on any more oxygen as any increase of oxygen at this time will result in an oxidizing flame which will burn the metal badly. The correct quantities of gases may further be detected by the hissing of the torch flame for the smaller tip (up to No. 6). The flame should emit a soft sound (purr), not a sharp irritating hiss, when correctly adjusted.

11. If the torch burns with an irregular contour to the cone, a feather, the flame is called a *carbonizing* flame because there is an excess of acetylene being used. But if the inner cone has a very sharp point, and if it hisses excessively, it usually means

that too much oxygen is being burned, and the flame is called an *oxidizing* flame, meaning that there is an excess of oxygen which will badly burn or oxidize the metals being melted. If the flame has a smooth inner cone, the flame is called a neutral flame.

Another method of adjusting the welding torch for correct pressure is as follows:

1. Turn on the cylinder gases as in the previous method.

2. Open the acetylene torch valve one turn. Turn the adjusting screw on the acetylene regulator in slowly, and when the acetylene starts flowing, light the acetylene. See Paragraph 40. Keep turning the acetylene regulator screw in until the acetylene is made to jump away from the torch, or the turbulence is correct as in the previous method.

3. Open the oxygen torch valve one turn. Turn the oxygen regulator adjusting screw in slowly until enough oxygen is being fed to the torch to consume completely all the acetylene, and a *neutral flame* is obtained. (The neutral flame may be recognized as in the method above.)

4. This method may be used in place of the first method; but in the case where the operator uses a long hose, and where the hose is bent in many different directions, the pressures do not stay constant. However, the first method assumes that the torch valves are in excellent condition and will not go out of adjustment. The operator has the choice of using either of the two methods, and will gradually choose the one which he prefers. The results of either one of these methods are generally identical.

8. Shutting Off the Torch

If the operator wishes to leave his station for just a few minutes, it is only necessary to close the torch valves and lay the torch aside until it is to be used again. However, if the equipment is not to be used for any length of time, it is recommended that the station be completely shut down; the proper method of shutting down a station is as follows:

1. Close the hand valves on the torch, preferably the acetylene valve first (this is to eliminate the smudge the pure acetylene gives).

2. Close the cylinder valves (tightly).

3. Open the hand valves on the torch.

4. Wait until the high and low pressure gauges on both the acetylene and oxygen regulators read zero.

5. Turn the adjusting screws on both the acetylene and oxygen regulators all the way out.

6. Close the hand valves on the torch (lightly) and hang the torch in a convenient place.

9. Welding Procedure

After the torch has been lighted and adjusted to the required flame, the correct use of the torch, or the correct handling of it during the welding task, is very essential in order to obtain good welding results.

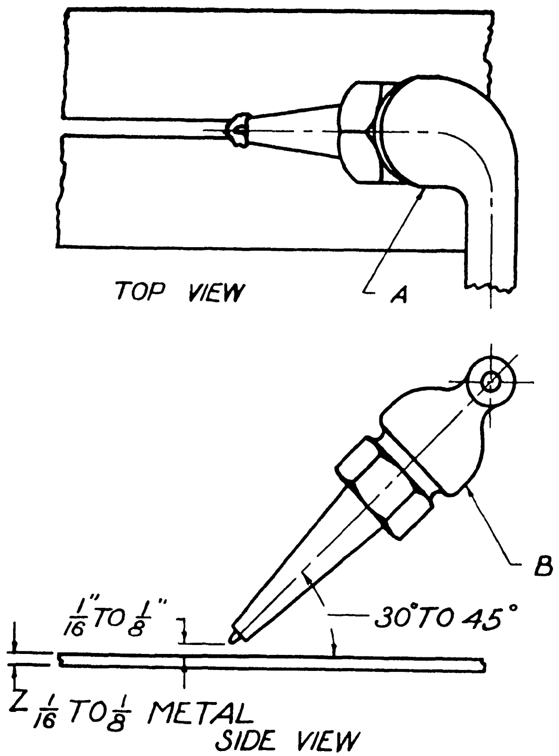


Figure 5. How to hold a torch when flat welding: A. Note the torch points along the direction of welding, B. The angle is less for thin metal and more for the thicker metal

First, and foremost, the required pressures and the correct size of the tip should be chosen for the particular task. If the torch is too small, welding will be impossible; but if the torch is too large, poor welds will result, because the weld will have to be made too fast; also the appearance of the weld will be unsightly. *A correct*

adjustment of the torch is absolutely necessary before welding of any kind can be done. For example, the following will be a description of the proper technique for making a butt weld on sheet steel $1/16''$ thick. The butt weld takes place in a horizontal position on a flat surface.

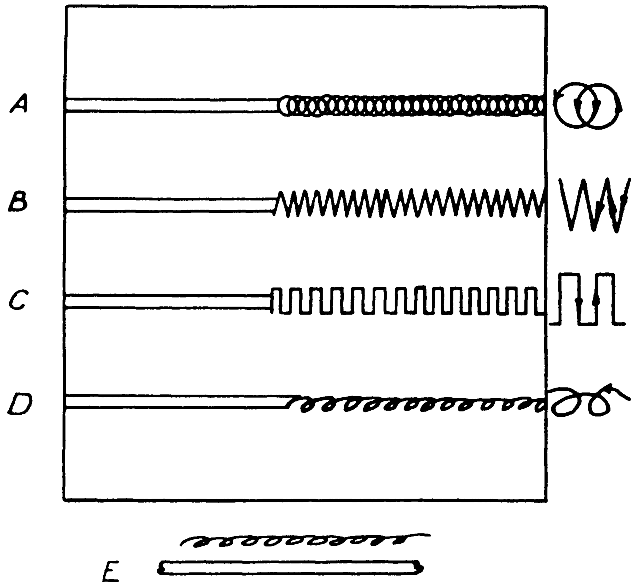


Figure 6. Torch Motions: A. Circular motion, B. Oscillating motion, C. Cross motion, D. Oval motion, this motion is also slightly into and out of the weld puddle as shown in E

1. The torch tip should point along the seam to be welded.
2. The torch should be held at a 30° to 45° angle with the surface of the stock. *Figure 5.*
3. The tip should point in the direction that the weld is to proceed.
4. The tip of the inner flame cone should be approximately $1/16''$ away from the metal surface.
5. A torch motion should be used and may be either of the oscillation, or of the circular style. In either case, however, the inner cone should never be allowed to go outside of the puddle bounds or boundary. *Figure 6.* The puddle is the molten spot on the metal, produced by the concentrated, high temperature flame.
6. For any particular thickness of metal, the width of the weld must be very consistent in order to obtain even penetration and

a nice looking bead. The width of the puddle will determine to a great extent the amount of penetration.

7. The filler rod, used for building up the welded joint, should be added to the weld only by putting the end of the filler rod in the puddle formed by the torch. Filler rod metal should never be allowed to drop into the puddle. The torch should never be used to melt the filler rod unless the filler rod is in the puddle. If the torch melts the rod, there is too much chance of oxidization. Fusion between the filler rod and the parent metal will be difficult. *Figure 7.*

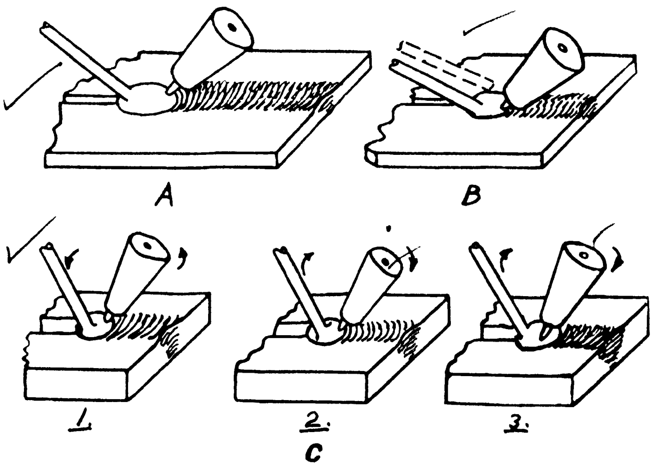


Figure 7. Torch and filler rod motions on thin metal (A and B) and thick metal (C: *1* Torch is on one side, filler rod on the other; *2* Torch is in the middle moving one way, filler rod is in the middle moving the other way; *3* Torch is on the other side and filler rod on the reverse side)

8. The appearance of the puddle, as the weld proceeds, is indicative of the kind of flame used. The neutral flame, when melting a good grade of metal will give a smooth, glossy appearance to the puddle; and the edge of the puddle away from the torch will have a bright bead, which moves actively around the edge of the puddle. If this bead is oversized, the flame is not neutral. Also, if the weld puddle bubbles and sparks excessively, it means that either a poorly adjusted flame or a poor and dirty metal is being used.

10. Types of Gas Welding Operations

To become proficient in the art of gas welding, certain fundamental exercises must be attempted and must be practiced until the welds can be performed consistently. The different funda-

mental gas welding operations, which are necessary to learn before one may be classed as a proficient welder, are:

1. Butt welding
2. Inside corner welding
3. Lap welding
4. Vertical welding of all kinds
5. Outside corner welding
6. Horizontal welding of all kinds
7. Over-head welding of all kinds

These welds should be performed on both thin steel and sheet steel of at least ¼″ thickness. After obtaining the necessary skill for these exercises, the welder may then proceed to study special welding applications, i.e., pipe welding, aluminum welding, cast iron, etc. *Figure 8.*

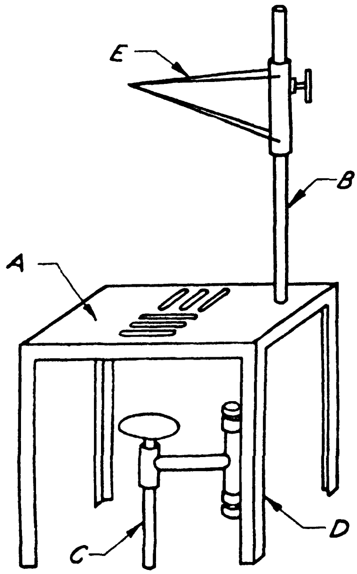


Figure 8. A universal welding stand for general welding and for practice welding: A. Cast iron top with slots, B. Iron pipe threaded into cast iron top, C. Fabricated stool, D. Angle iron bench, E. Adjustable holder for vertical, horizontal, and overhead welding

11. Torch Adjustments

The torch may be adjusted to produce the following flame characteristics:

1. Neutral flame
2. Carbonizing flame (carburizing)
3. Oxidizing flame

In general, the neutral flame is the flame desired; however, in welding aluminum, in brazing, and in other operations where oxidizing of the metals would interfere with welding, a slightly carbonizing flame should be used. *Figure 1* illustrates the appearance of each of the above flames. While a slightly carbonizing flame may be recommended for certain work, usually a perfectly neutral flame would serve equally as well. However, because of the slight fluctuation in gas pressures, it is difficult to maintain a perfectly neutral flame over a period of time, and it may vary from neutral to slightly oxidizing or carbonizing. Therefore, in order to avoid the possibility of running into an oxidizing flame, a slightly carbonizing flame is the safer to use.

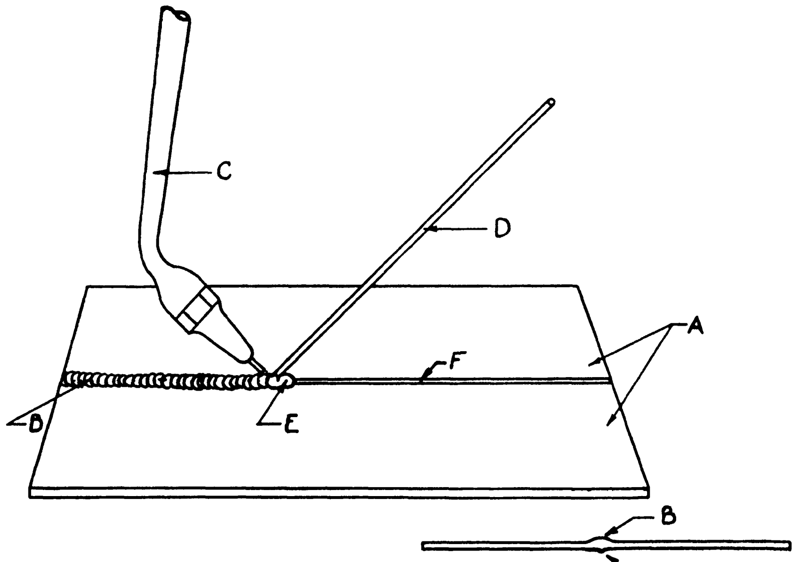


Figure 9. Flat Welding: A. Parent metal, B. Bead, C. Torch, D. Filler rod, E. Puddle, F. Gap in the Seam, G. Penetration

12. Torch Position and Movements

The torch may be held in two different positions according to the type of welding being done. These positions are called:

(a) Forward welding

(b) Backward welding

The position of the torch, the work, and the filler rod for both of these welding positions are shown in *Figures 9 and 10.*

Forward welding, as shown in the above figures, provides that the torch be held at an angle of 30° to 45° with the work. The flame spreads over the work in the direction in which the weld is

progressing. The spreading of the flame in the direction of the weld tends to preheat the metal before it comes under the high temperature welding part of the flame. This makes for economy in welding.

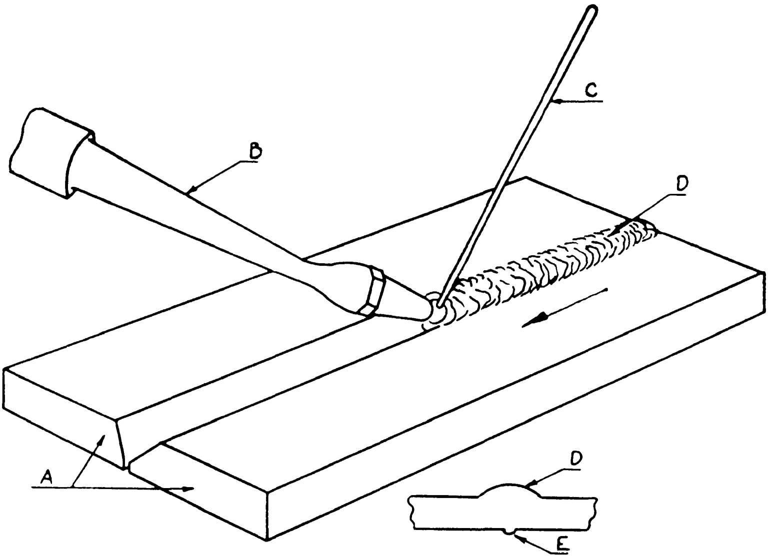


Figure 10. "Backward" method of welding heavy plate: A. Bare metal, B. Torch, C. Filler rod, D. Build up, E. Penetration

Leftward

Backhand welding, provides that the torch be held at an angle of 30° to 45° with the work, and the flame directed over the portion of the work which has been welded. The directing of the flame tends to anneal the weld and relieve the welding stresses to a great extent. In addition, the direction of the flame tends to help the welder in forming a good bead, and in attaining good penetration of the weld. Backhand welding is used commonly in welding cast iron or drain pipe, and in welding thick, heavy sections in which the welding stress must be relieved. In backhand welding, the continued flare of the torch on the hot portion just welded tends to maintain a rather large puddle of molten metal. In order that the edge of the puddle may solidify into a bead, it is necessary to move the flame upward, at frequent regular intervals. This allows the edge of the puddle to cool slightly and solidify.

13. Puddling

Before attempting a weld of any kind, it is recommended that the beginners practice "Puddling." Puddling is a fundamental

part of welding, because in all welding a molten puddle of metal is carried across the part to be welded. This is true in all forms of welding, both gas and electric arc. The characteristics of the puddle of molten metal indicate the penetration, torch adjustment, torch handling and movement. These characteristics, as indicated in the condition of the puddle, are the guide which the experienced welder follows in producing a good weld. The welder should be able to produce five (5) beads by puddling, each at least 5 inches long, consecutively without melting any holes through the metal, and at the same time secure good penetration. The beads must also be straight (in line) and even in width. If the beginner can do this, he has learned torch operation; he now knows the theory of the weld puddle sufficiently to proceed with the learning of the manipulation of filler rod.

The size (diameter) of the puddle will be in proportion to its depth; therefore, the operator may judge the depth, or penetration, of a weld by watching the size of the puddle of molten metal. On very thin metal, the penetration or depth of the puddle will be greater in proportion to the width than will be the case with thicker metal.

The appearance of the surface of the puddle will indicate the condition of adjustment of the torch. With a neutral flame, the surface of the puddle will be bright and clean with little agitation or surface movement. If the flame is oxidizing, the puddle will appear to boil and this will be accompanied by considerable sparking. The surface of the puddle will have a dull and dirty (soot) appearance, if the flame is carbonizing to any great extent.

The tip of the inner cone of the torch flame must be held within the boundary of the puddle at all times. The correctly adjusted flame over the puddle prevents the atmosphere oxygen from coming in contact with the surface of the puddle and causing an oxidizing condition.

Never allow the torch to be brought so close to the puddle surface that the top of the inner cone touches it. The tip of the inner cone should be held $\frac{1}{16}''$-$\frac{1}{8}''$ from the puddle surface. If the puddle sinks too far, indicating too great a sag on the bottom of the metal, lower the angle of the torch rather than draw the torch away from the surface of the puddle.

14. Use of Filler Rod

Puddling without the use of a filler rod is not considered a satisfactory means of welding, particularly where maximum strength

of the weld is desired. This is because in fusing the metal surfaces together in the puddle, the thickness of the metal at the weld will be reduced. In order to obtain a strong weld, a filler rod of the metal desired is fed into the puddle to increase its depth, and to increase the thickness of the metal at the weld. See paragraph 43 for specifications of filler rods. The bead in a correctly made strength weld should be slightly crowned for extra thickness and strength of the weld. Figure 7, illustrates the method in which filler rod material is added to a weld to make a slight crown to the bead.

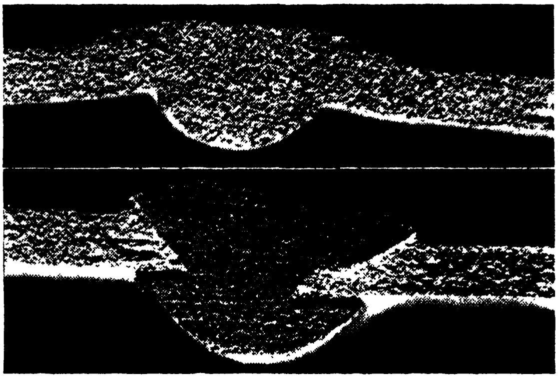


Figure 11. A macrograph (4X) of two butt welds. The top weld used as filler metal, the same metal as the base metal; while the bottom weld used a commercial filler rod as filler metal. Note the penetration and fusion

To weld with filler rod, bring the torch to the joint where the weld is to start; melt a small puddle on the surface of the work, joining the surfaces to be welded. With the other hand, bring the filler rod to within about 3/8″ of the torch flame and 1/8″ from the surface of the puddle. In this position, the filler rod will become white hot and may be dipped into the puddle.

Some of the filler rod will melt and mix with the parent metal. Enough filler rod metal should be added to raise the puddle to a slight crown. At the same time, continue the torch motion without interruption. As soon as enough filler rod metal has been added, withdraw the filler rod to the position described above, which should maintain the end of the filler rod in a white hot condition.

If the filler rod is withdrawn too far from the torch, it will become too cold, and will cool and chill the puddle when it is again inserted into it. On the other hand, if the filler rod is held too close to the flame of the torch, it will become too hot; and if it should become molten, drops of molten filler rod will be blown by the flame upon the cooler joints of the metal being welded. Such a condition

will result in a very uneven bead and probably poor penetration of the weld.

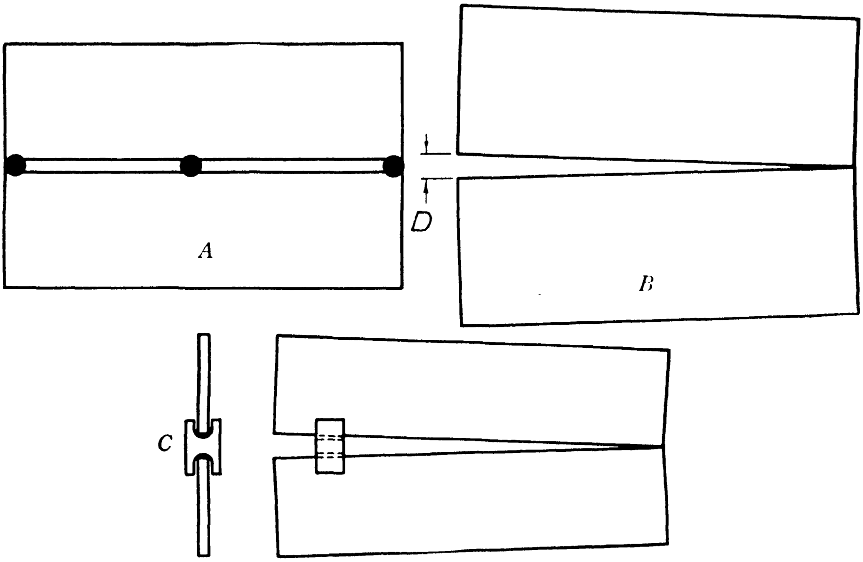


Figure 12. Methods of allowing for contraction of the metal during welding: A. Tack method, B. Tapered gap method, C. Clamp method, D. ¼" gap opening per foot of ream

It should be pointed out that a good weld, meaning good fusion, good bead, and good penetration, is obtainable only by attaining skill in the handling of the welding torch and the filler rod simultaneously and in harmony one with the other. This means that the torch motion should be constant in forward speed, in the width of the motion, and in the proper distance the cone is allowed to come to the metal; the slant of the torch in respect to the surface should always be the same.

As one welds, the torch will occasionally "pop." This small explosion at the flame is the result of several avoidable conditions. The most frequent cause of the "popping" is due to pre-ignition of the gases. Some causes of pre-ignition are as follows:

1. The gas is flowing out too slowly and the pressures are too low for the size tip (orifice) used. Correct this trouble by using a higher pressure on both the oxygen and acetylene.
2. The tip becomes overheated through overuse or it is operating in a hot corner, or it is too close to the weld. Correct this by cooling the tip.
3. The inside of the tip may be carbonized or a hot metal particle may be lodged inside the orifice of the tip. Correct this by

carefully cleaning the tip. See both paragraphs *38* and *288*.

One extreme cause of a torch popping which happens very rarely is when the inner cone of the flame is submerged in the puddle.

A "backfire" is a condition where the gas burns back (combustion takes place) to the regulator. In this case, the hose should be replaced and the torch and regulators should be replaced or overhauled.

There are two types of Backfires:

1. Back into the acetylene hose, when oxygen feeds back into the acetylene hose, combustible mixture forms and a violent explosion may result. A clogged barrel or mixture passage along with an excessive oxygen pressure may cause this trouble.
2. Back into the oxygen hose, oxides violently formed inside the hose if the line is raised to the ignition point will cause an explosion.

15. Butt Welding

Butt welding is one of the most common types of welds which may be made with the oxy-acetylene torch. The following instructions will aid the beginner in making this type of weld on thin steel.

Procure two pieces of metal approximately one inch wide and five inches long. Place the two pieces of metal between two bricks, permitting the bricks to support the ends of the metal. Touch the edges of the two pieces of metal together at the end where the weld is to start. As the weld proceeds along the joint, the metal upon cooling from a molten state tends to pull the two pieces of metal together. This shrinkage may cause the edges to lap one over the other, or warp the metal. The operator now has the choice of doing one of three things to prepare the metal for the expansion and contraction which occurs during welding.

(1) Taper the gap between the two pieces of metal to allow for contraction. *Figure 12.* The approximate contraction is from $\frac{1}{8}$ to $\frac{1}{4}$ inches per foot of length of the metal.

(2) Another method is to fuse (or tack) the ends of the two pieces of the metal together before proceeding with the welding. This method will produce an internal strain to some degree, but will keep the ends sufficiently in line to enable the operator to make a good weld.

(3) A third method is to use especially prepared wedges which are placed between the two pieces of the joint to prevent the contraction of the metals as the weld cools. This method is more

generally used with longer joints than with the practice exercise mentioned above.

Welding 1/16″ metal will necessitate the use of No. 4 tip used with an equal pressure torch. Light the torch, adjust it to a neutral flame, and proceed as follows:

Bring the torch to the point where the weld is to start, holding the torch at a 30 to 45 degree angle so that the tip points along the direction of the weld, and so that the green cone is approximately 1/16″ away from the metal. With the other hand, bring the filler rod approximately 3/8″ away from the welding torch and just above the metal (about 1/8″). The torch flame will melt a puddle which should extend equally over the two pieces of metal.

The torch now advances a very short distance, as the motion continues, until the puddle again reaches the size of the previous one. The filler rod is again dipped into the puddle and the puddle is built up to a crown as previously. This should continue throughout the length of the weld joint. The operator must use a continuous torch motion, whether it is a slight motion or a very distinct one. He should keep it a consistent distance from the metal. The torch angle must remain unchanged, and the filler rod should be added at consistent and specific intervals. After the weld has been finished, allow it to cool until it may be picked up by the hand and inspected.

16. The Appearance of the Weld

The weld should be of consistent width throughout its length.

It should be perfectly straight so that the two edges form two straight lines, one parallel to the other.

The weld should be slightly crowned, being built up above the parent metal.

The weld should have the appearance of being fused into the parent metal, not having any distinct line of demarcation. It should have a blended appearance, and not have a distinct edge between it and the parent metal.

The surface of the weld should have a ripple throughout its length. The ripple should be evenly spaced, and the weld should be built up to a consistent height above the parent metal.

The weld should have a clean appearance. There should be no color spots, no scale on the weld, and no rough pitty appearance to the weld.

Turn the specimen over and check the penetration. The degree of penetration will be indicated by the sag of the lower surface of the weld. The sag should be slight, and yet penetration should be

obtained throughout the length of the weld. The amount of sag under these conditions should not be more than $1/64$ to $1/32$ inch. The penetration is hard to determine; the easiest way to test for it is to place the specimen in the vise, or jig, with the weld held at the edges of the jaws. The upper half of the specimen is then bent, closing the two edges upon the welded part like a book. If the weld has not penetrated satisfactorily, it will crack open at the joint as it is being bent.

The welder will find it extremely difficult to obtain consistent and efficient penetration. It is possible to secure a very good weld with abnormal penetration, and to build the upper surfaces of the weld up to the correct height. This weld will be of sufficient strength, but a weld of this nature will cost much more than the weld described above. It is only necessary to produce a weld as strong, or a little stronger, than the original metal and no more.

17. Inside Corner Welding (Inverted "Tee")

A fairly easy exercise to perform, but one in which the operator may find it extremely difficult to obtain sufficient penetration, is the inside corner weld. Two pieces of $1/16''$ stock are placed with their

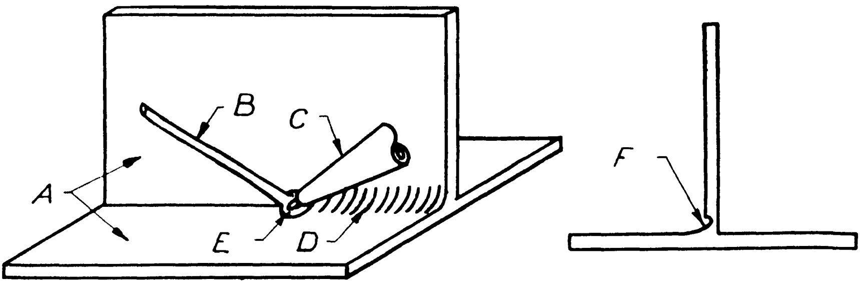


Figure 13. Inside Corner "Tee" welding: A. Parent metal, B. Filler rod, C. Torch, D. Bead, E. Puddle, F. One must be careful not to undercut

surfaces at right angles to each other, either in an "L" formation or in an inverted "T" formation, and one inside corner is welded. *Figure 13.* When welding in this position, the torch flame is placed inside of the "L" during the welding process. As it is difficult to obtain sufficient oxygen from the air to complete the combustion of the acetylene, it is necessary to open the oxygen torch valve slightly to provide a little extra oxygen. This would result in an oxidizing flame under normal circumstances, but in this special case, it produces a neutral flame. The exercise may be set up in two different ways:

(1) The two pieces may be set at an angle of 45° from the

horizontal forming a trough. The operator will find that the exercise with the specimen set up in this manner is very easy.

(2) A second method, which is the preferred one, is to have one piece horizontal and the other vertical, with the edge of the vertical piece touching the middle of the surface of the horizontal piece. Before welding them in this position, the operator should tack the ends to keep them in line while welding. It will not be

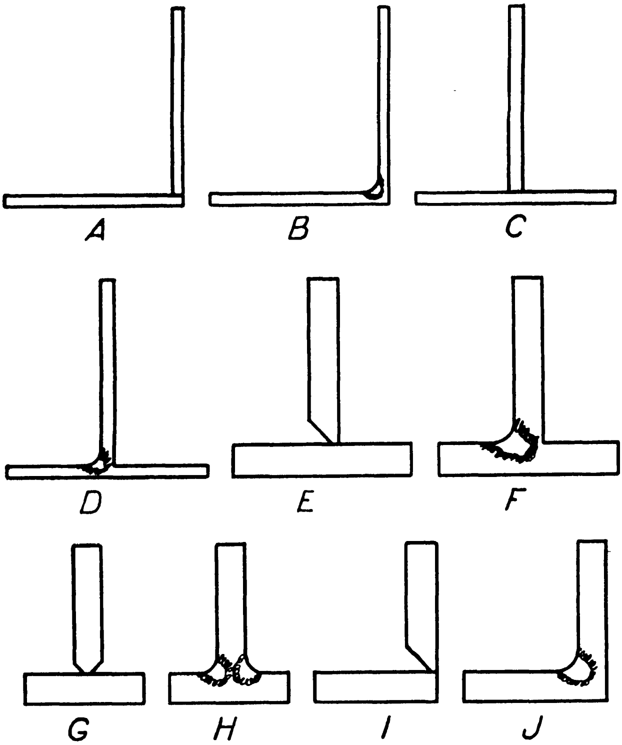


Figure 14. Preparing metal for inside corner edge and tee welding: A. Thin metal edge weld, B. Same as A but after welding, C. Tee weld, thin metal, D. Tee weld after welding, E. Single chamfer tee weld for thick metal, F. After welding, G. Double chamfer "Tee" weld, H. After welding, I. Edge weld, single bevel for thick metal, J. After welding

necessary to provide for expansion and contraction, in this case, inasmuch as the metals are pulled one against the other. *Figure 14.* The mechanics of handling the torch and filler rod will be the same in this exercise as in the previous one. The operator will find that very little torch motion is necessary; also, it is very important to produce a puddle before attempting to add the filler rod; otherwise, insufficient penetration will result. To secure fusion into the vertex of the weld one should hold the torch as

close as possible without touching the metal then draw it back slightly when adding the filler rod. After the weld is completed, inspection should show a good bead, good fusion, consistent width of the weld, a clean appearance, and an equal distribution meaning that ½ of the weld is on one piece and ½ on the other. Also the vertical piece of metal especially should not show any indications of having some of its metal melted away leaving it thinner (undercutting).

To test for penetration, the two pieces of metal are closed together like the pages of a book on the weld, and the lack of penetration or fusion is indicated by the added metal peeling away from the parent metal. The beginner is sometimes tempted to use different sized filler rods for the same weld. This should not be done, for if 3/32 inch filler rod is being used, it will be extremely difficult to add enough filler rod to obtain a good weld if a change is made to 1/16 inch filler rod; also there will be a tendency to burn the smaller sized filler rod. If one changes to 1/8 inch filler rod after having used 3/32 inch filler rod the following troubles might result:

(1) The filler rod will cool the puddle while it is being added and prevent consistent welding.

(2) There will be a tendency to add too much filler rod, destroying penetration and building the weld higher than it should be on the top surface.

Whether one should use a 1/16″, 3/32″, or 1/8″ filler rod is not so important as it is for the operator to adhere to one size after once becoming used to it for a certain thickness of metal. One general rule to follow is that one should never use a filler rod of greater diameter than the thickness of the metal.

18. Lap Welding

A rather common welding procedure, used extensively in industrial work, is the lap weld. This consists of lapping one piece of sheet steel over the one to which it is to be welded. *Figure 15.* This weld should be first performed on a flat surface. Although the welding technique is typical, several things must be kept in mind in order to obtain a satisfactory lap weld.

(1) It will be found extremely difficult to heat the bottom metal to a molten state before the top metal edge melts and disappears, making the weld very ragged. One method of preventing this occurrence is to concentrate the torch on the lower surface by angling the torch away from the top metal. *Figure 16.*

(2) Another precaution is always to make the welded portion

(filler metal) at least as thick as the original metal. It will be found most difficult to do this with a lap weld. The only way to procure a good result is to crown the weld slightly.

The beginner will have a tendency to perform this weld without heating the bottom metal sufficiently to procure fusion. However, the destructive test will quickly show the lack of fusion at this point. Before testing the specimen, the appearance of the weld

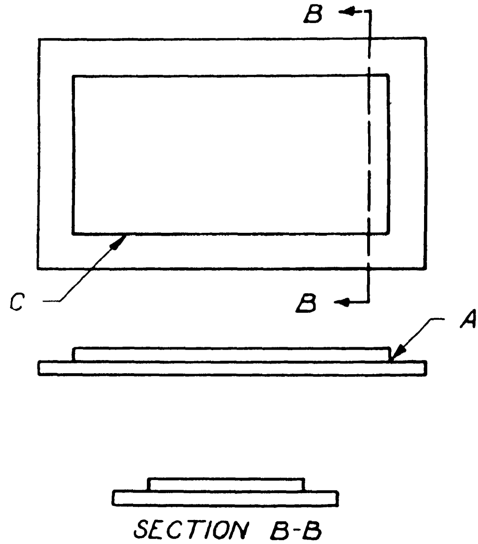


Figure 15. Setting up the metal for lap welding: A. It is important to fit the two pieces tightly together, C. Edge to be welded

should be closely observed for such things as bead, consistency of width, cleanliness, etc. The metal should not sag on the reverse side of the bottom piece (too much penetration), and the bead should be straight.

19. Outside Corner Welding

An interesting exercise, which is somewhat different from those previously explained, because no filler rod is used on the sheet steel, is called the outside corner weld. This exercise teaches the method of welding by using some of the parent metal as the filler rod. It is a simple exercise, showing the advantage of beveled edges of two metals. The pieces are placed one against the other, at right angles so that one (the vertical piece) extends up beyond the surface of the horizontal sheet approximately $\frac{1}{32}$ to $\frac{1}{16}$ inch. This extended metal serves as the filler rod metal. The two pieces are then tacked together at their ends. *Figure 17.*

The weld must have a good penetration, but the penetration should not show on the inside corner. The operator will find that very little torch motion is ideal for this exercise. Further, the torch tip should be slightly tilted, making the flame point inward toward the flat or horizontal surface. The weld should be all on the horizontal surface; none of it should run over on the vertical edge. This is necessary because in many cases of metal finishing, the weld is made into a right angle corner by grinding the excess

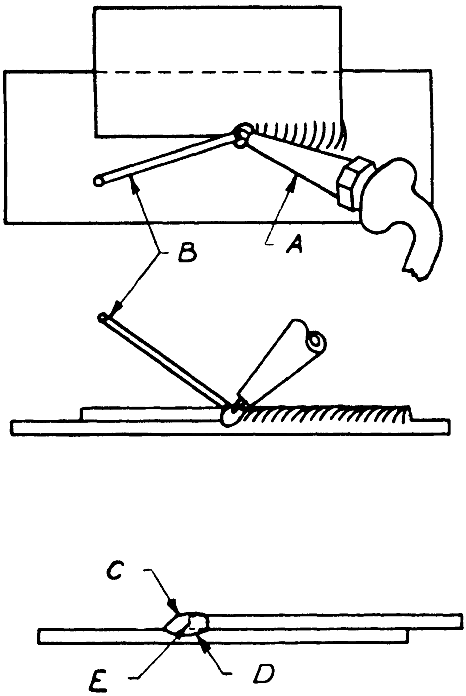


Figure 16. Position of torch in lap welding: A. Torch tip, B. Filler rod, C. Bead, D. Penetration, E. Showing how much of the edge of the metal should be melted away

metal from the one side. After checking the weld for appearance, the penetration may be tested by bending the two pieces of metal open like the pages of a book; any cracking or breaking of the metals at the joint will indicate a lack of penetration. In both horizontal and vertical welding, it will be found that more efficient penetration may be obtained than with flat welding. *Figure 18.* The operator will have little difficulty in obtaining a good looking bead, but it is difficult to make a vertical or horizontal weld have as good an appearance as a flat weld.

20. Vertical Welding (On a Vertical Surface)

All of the preceding welding operations have been performed where the weld has been in a horizontal direction and on a horizontal surface (Flat Welding). It is best to practice this type of welding until one becomes thoroughly proficient. However, it is also necessary that the operator become equally proficient in vertical welding, horizontal welding, and over-head welding.

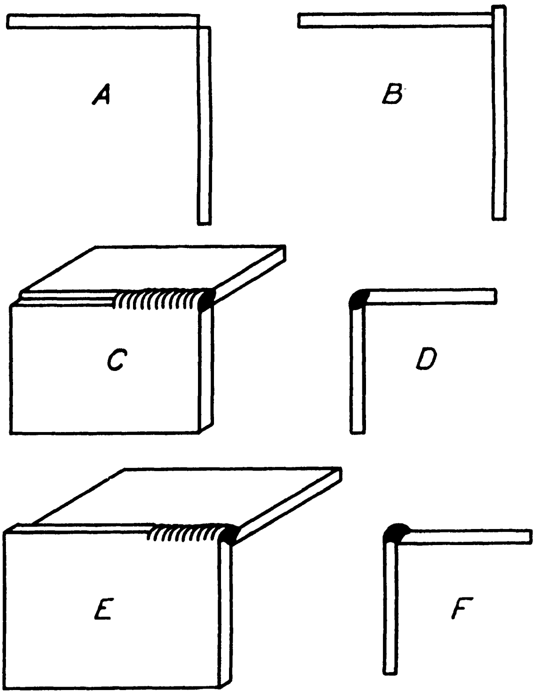


Figure 17. Outside corner welding: A & B. End views of two different seams, C. Showing A partly welded, note the position of the puddle and the filler rod, D. End view of A after welding, E. Showing B partly welded, F. End view of B after welding

Vertical welding consists of welding in a vertical direction on a vertical surface; all of the above exercises should be performed vertically including butt welding. *Figure 19.* The welding will not be found difficult after the first few attempts if the following precautions are observed:

1. The weld proceeds upward. The torch is inclined from the surface of the metal at an angle of approximately 15° to 30°. The torch tip is pointed up. This enables the gas velocities to keep the molten metal from falling, or sagging, because of gravitational pull.

2. A very small torch motion should be maintained to enable the gas velocities to keep the molten metal continually in its position.

3. Bead, fusion, and penetration should be checked according to the methods recommended in the previous paragraphs.

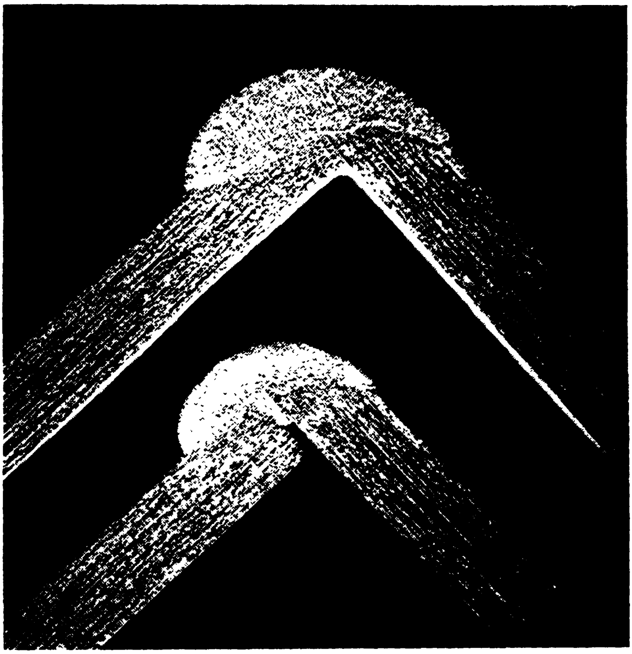


Figure 18. Outside corner welds (a 4X macrograph) showing a properly penetrated weld at the top and a partially penetrated weld at the bottom

21. Horizontal Welding (On a Vertical Surface)

This consists of welding a horizontal joint on a vertical surface. This kind of welding should also be practiced on butt welding, inside corner welding, and lap welding. *Figure 20.* The one precaution to be noted in order to accomplish an excellent welding job is that the torch tip instead of pointing directly along the weld should point at a slightly upward angle. This will enable the velocities of the gases to keep the molten metal from sagging. It will be found that more efficient penetration is obtained in both horizontal and vertical welding than in flat welding. The operator will have little difficulty in obtaining a good looking bead, but it is difficult to make a vertical or a horizontal weld have as good an appearance as a horizontal weld on a horizontal surface (Flat Weld).

22. Overhead Welding

The practice of overhead welding is extremely difficult when performed with a gas welding torch. *Figure 21.* It requires consistent, diligent practice by the operator to enable him to reach any degree of skill. The operator should protect himself with work clothes of good durability and with gauntlet gloves; he should not wear oxford shoes when performing this exercise. If the operator has not developed the skills described previously, he will find that it is

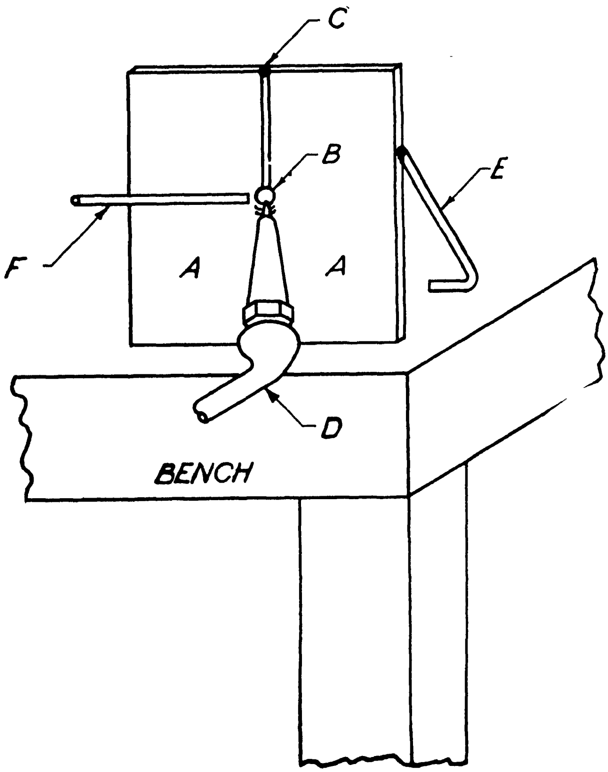


Figure 19. Vertical welding a butt weld: A. Parent metal, B. Puddle, C. Tack, D. Torch, E. Parent metal brace, F. Filler rod

almost impossible to apply the filler rod at the right moment. Overhead welding should be practiced on all the standard forms. At least two excellent samples of each type of joint should be obtained before the student has had enough practice. The exercise should be mounted approximately from six to twelve inches above the operator's head to be most comfortable, and the welder should stand to one side of the seam, welding parallel to his shoulders.

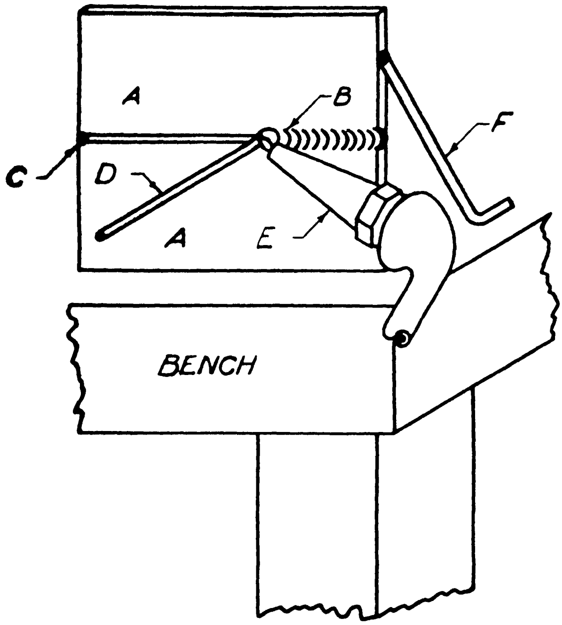


Figure 20. Horizontal welding a butt weld: A. Parent metal, B. Bead, C. Tack, D. Filler rod, E. Torch, F. Parent metal brace

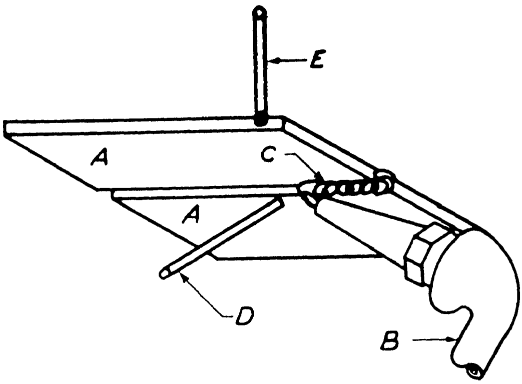


Figure 21. Overhead welding a butt weld: A. Parent metal, B. Torch, C. Bead, D. Filler rod, E. Parent metal holder

23. Review Questions

1. What is oxy-acetylene welding?
2. In what country was it first used?
3. What materials are used when manufacturing acetylene?
4. How is oxygen manufactured?
5. What is the temperature of the oxy-acetylene flame?
6. What is the chemical formula for acetylene?

7. Does the air help burn the acetylene?
8. Does oxygen burn?
9. What is fusion?
10. What should the welding flame do?
11. What shouldn't the welding flame do?
12. Where is the hottest part of the flame?
13. At what angle should the torch tip be held when flat welding?
14. Should a torch motion be used?
15. Is torch motion always necessary?
16. How far should the torch be held away from the work?
17. In what direction does the tip point when welding?
18. Why are correct torch pressures important?
19. Why must the regulator adjusting screws be turned out before opening the cylinder valves?
20. Why should the cylinder valves be opened slowly?
21. What keeps the molten metal from sagging in horizontal welding?
22. How should the molten metal be kept from sagging in horizontal welding?
23. What is the best torch position for vertical welding?
24. How often should filler rod be added to a weld?
25. What determines how much gas pressure is used for a gas welding torch?

CHAPTER II

OXY-ACETYLENE WELDING EQUIPMENT AND SUPPLIES

The welder must have a thorough knowledge of the various parts of welding equipment and of welding supplies. This understanding is necessary to secure safe conscientious use of the equipment, and to obtain the best results from the materials on hand. Safety also demands that the operator should thoroughly understand the characteristics of all types of equipment and supplies.

24. The Complete Oxy-Acetylene Welding Station

The welding station apparatus necessary to provide a degree of completeness to facilities for welding varies. The parts of the complete station and its equipment are shown in detail in their order of progression from the gas supply to the torch tip. *Figure 3.* The variation in the nature of the various parts and accessories that make up a welding station are shown below in tabular form.

The station consists of:

1. Gas Suppliers
    - a. Oxygen
    - b. Acetylene
        - (1) Cylinder
        - (2) Generators
    - c. Hydrogen
2. Regulators
    - a. Nozzle type
        - (1) Oxygen
        - (2) Acetylene
    - b. Stem type
        - (1) Oxygen
        - (2) Acetylene
3. Gauges
    - a. Oxygen
        - (1) High pressure
        - (2) Low pressure
    - b. Acetylene
        - (1) High pressure
        - (2) Low pressure
4. Hose
    - a. Oxygen
    - b. Acetylene
5. Torches
    - a. Equal pressure type
    - b. Injector type
6. Goggles
7. Lighters

25. Oxygen Cylinders

Oxygen is manufactured as pure as possible and is stored in cylinders of different sizes, which are usually painted yellow and

green. The gas is originally placed in the cylinder at a pressure of approximately 2,000 lb./sq. in. gauge. This pressure varies according to the room temperature as may be noticed in Paragraph 301. Oxygen is manufactured by two different processes. One method involves liquefaction or liquefying of air and the subsequent release

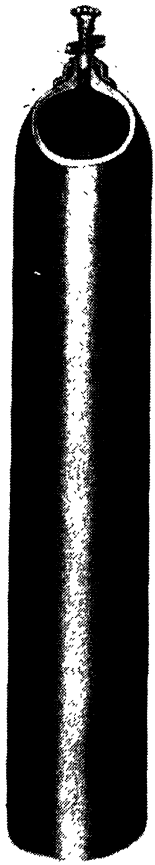


Figure 22. Oxygen cylinder. A 220 cubic foot capacity. Note the one piece construction
(Courtesy of: Air Reduction Sales Company)

of the oxygen which is then compressed and stored in cylinders. The other method is by electrolysis, in which the oxygen is secured by breaking up water into its two gases—oxygen and hydrogen. This is accomplished by means of an electric current. See Paragraph 1. The oxygen is then captured and stored in cylinders. This process is used particularly in areas which have a commercial use for the hydrogen liberated. Of the two methods, the liquefac-

tion or liquefying of air is said to be the least expensive and is generally the most popular. Commercial oxygen, that is sold on the American market, is between 99 and 100% pure.

A new method of distributing oxygen has recently come into use. This consists of shipping the oxygen while it is in the liquid form,

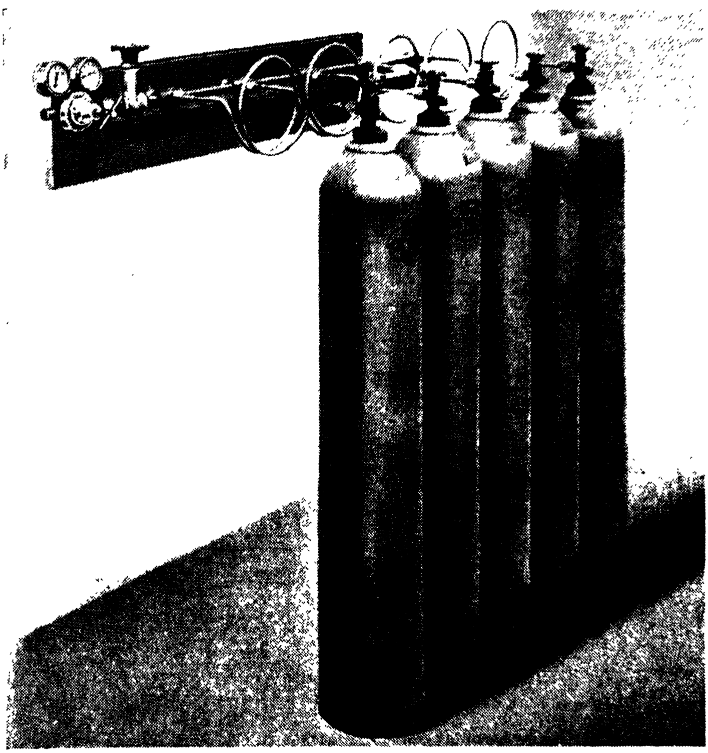


Figure 23. An Oxygen manifold for five cylinders. A master shut-off valve is located between the regulator and the cylinders. The complete arrangement is usually enclosed

(Courtesy of: Air Reduction Sales Company)

and providing equipment to vaporize the oxygen as needed. Because of the high-pressure of oxygen stored in cylinders, the pressure being equivalent to 1 ton of pressure upon one sq. in. of area, the cylinders must be of very sturdy construction. The Interstate Commerce Commission (I.C.C.) has prepared specifications for the construction of these cylinders. They are forged in one piece, no part of which is less than 3/8" thick. The steel used is armor plate, high-carbon steel. *Figure 22.* Cylinders are periodically tested with water at a 3,360-lb. hydrostatic pressure. The cylinders are also regularly annealed and cleaned with a caustic solution. The valve, located in the upper end of the cylinder, incorporates a

pressure safety-device. This valve is of special design to withstand the pressure, and is called a "back seating" valve, meaning that when the valve is turned all the way out, the stem is sealed to prevent leakage around it. This valve should be turned all the way out when in use. The gas outlet fitting is a standardized male thread which fits all American standard oxygen regulators.

Threads on the body of the cylinder surrounding the valve provide a means whereby a heavy cap may be screwed over the valve to protect it from injury during shipment. If the cylinder valve should ever be broken off, the terrific pressure of gas in the cylinder, upon escaping, would burn any material touched, and it would also give the cylinder a rocket velocity. Because of this it is always recommended that the cylinders be handled by no less than two persons per cylinder. It is also recommended that when being shipped, the cylinder be clamped so that there is no danger of its being tipped over or dropped. The cylinders, when full or partially full, should never be allowed to stand by themselves without adequate support.

Cylinders should always be kept right end up, and the valve closed when the cylinder is not in use, whether it is full or empty.

Many large industries, such as production shops and the like, do not incorporate an oxygen cylinder in each welding station. Instead, the oxygen is piped from a separate room to the stations. This system is called a manifold installation. The pressure in the manifold is usually regulated to be between 50 to 100 lbs./sq. in. Installations in which from 2 to 20 cylinders are connected in the same manifold are very common. Manifolds are used when large quantities of oxygen are needed, such as for heavy cutting and the like. *Figure 23.* In manifold installations, the copper tubing (pig tail), leading from the cylinders to the pressure reducing mechanism, should be frequently annealed and softened; a one-month period should be the limit between anneals. This is because the tubing, when subjected to the high pressure in the cylinder, it becomes brittle crystallized and may burst.

Oxygen is furnished by the manufacturers at a certain price per 100 cu. ft. Cylinders remain the property of the oxygen manufacturer and are loaned to the oxygen consumer at a low rental. The price of an oxygen cylinder alone, when purchased in large quantities, is approximately $35. Oxygen sold in liquid form is delivered in large tanks shaped like a thermos bottle. This eliminates the overhead resulting from a tie-up of a large quantity of cylinders.

26. Acetylene Cylinders

Acetylene is made available for consumption by two different methods. The one already mentioned is to obtain it in cylinder form; the other method is to use an acetylene generator. Acetylene is a gas of the hydro-carbon family; it consists of two parts of carbon and two parts of hydrogen, and has a chemical formula (C_2H_2).

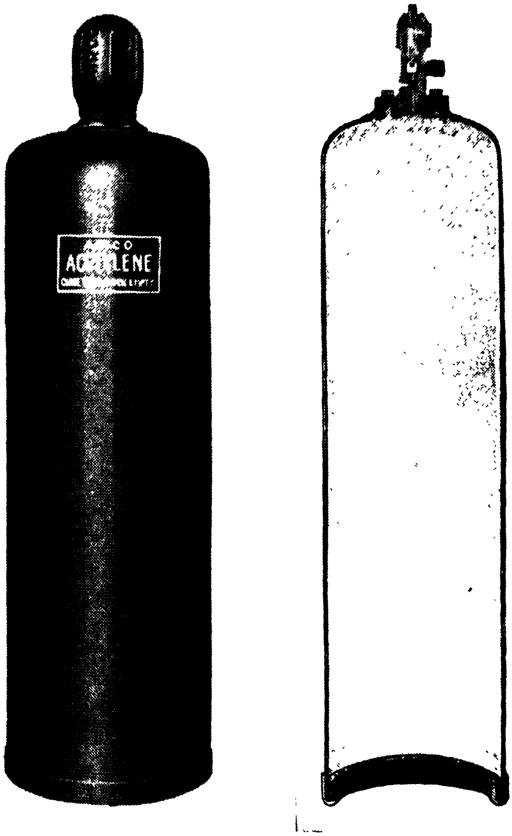


Figure 24. An Acetylene cylinder ready for shipment and a cut-away cylinder showing the porous filler and the fuse plugs at top and bottom of cylinder
(Courtesy of: Air Reduction Sales Company)

Acetylene is manufactured by the chemical combination of calcium carbide with water. Calcium carbide is a crystalline substance which, when mixed with water, reacts chemically and gives off acetylene. The chemical formula for the procedure is, $CaC_2+H_2O=C_2H_2+Ca(OH)_2$. The acetylene gas from this chemical action is passed through filters and purifiers before being stored in cylinders.

The problem of storing the gas is exceedingly difficult. A peculiar thing about acetylene gas is that it cannot be safely stored as a

pure gas at a pressure exceeding 15 lbs./sq. in. This means that in order to distribute the acetylene by the cylinder method, some means must be devised whereby the acetylene may be stored by some method other than under direct compression. The method most used consists of dissolving the acetylene in acetone under a high pressure. The acetone is further stored in some pulpy substance to further safe-guard the acetylene.

Figure 24A. A complete oxy-acetylene portable welding station
(Courtesy of: Air Reduction Sales Company)

This cylinder is also fabricated according to I.C.C. specifications. The cylinder is usually shorter and has a greater diameter than the oxygen cylinder; it is usually painted black. One may also notice that the base of the cylinder is concave and that two plugs are threaded into the base. *Figure 24 and Figure 24A.* Upon close

inspection, one may see that the center of these plugs is made of some soft material. These are safety plugs and are specially constructed so that a temperature exceeding 165° F. to 215° F. will melt the core and allow the gas to escape before the pressure bursts the cylinder. Usually the top is slightly crowned and the cylinder valve is threaded into it. The cylinder valve stem is opened and

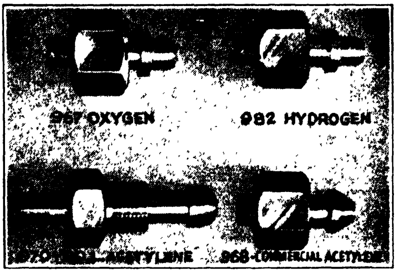


Figure 25. Fitting Details
(Courtesy of: Victor Equipment Company)

closed by means of a 3/8″ square opening wrench. It is recommended that this cylinder valve never be opened more than 1/4 to 1 1/2 turns for the sake of safety.

The inside of the cylinder is tightly packed with the composition substance mentioned previously. This substance is either soft asbestos packing, or a residue called corn pith. This material is then saturated in a liquid called acetone, a liquid having a banana oil odor. Acetylene will dissolve into the acetone when placed under pressure; a large quantity may be stored in a relatively small space by this method. A large acetylene cylinder when subjected to a pressure of about 250 lbs./sq. in. will absorb approximately 250 cu. ft. of acetylene. The acetone is able to dissolve the acetylene by the same method by which coffee dissolves or absorbs sugar, the acetylene gas molecules fitting in between the acetone molecules and seemingly occupying but little space inside the cylinder.

The amount of acetylene in a cylinder can be determined accurately only by weighing the cylinder. The amount cannot be accurately estimated by the pressure inside the cylinder. This is because the pressure of the acetylene coming from the acetone will vary but little until it is all used up.

27. Acetylene Generators

Because of the rather difficult problem of procuring enough acetylene from cylinders for large consumption, many heavy users

prefer to manufacture their own acetylene. Acetylene generators are available for this purpose. They come in two styles:

1. The low pressure type
2. The high pressure type

They work very efficiently, and usually furnish acetylene at a cheaper rate than is possible when purchased in cylinders.

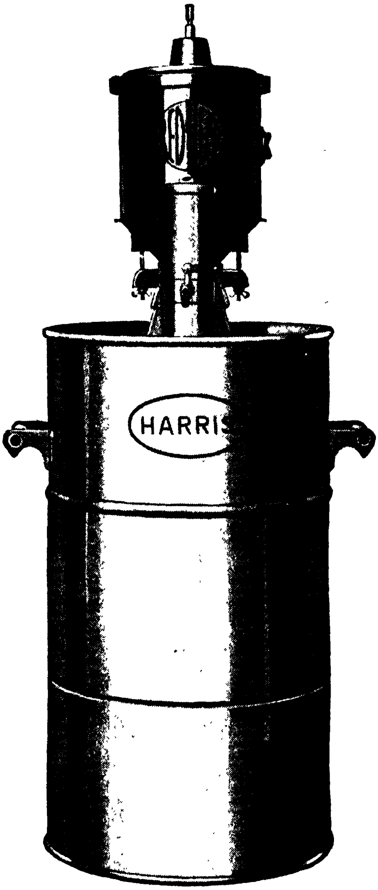


Figure 26. Acetylene generator
(Courtesy of: Harris Calorific Company)

The low pressure type may be of either the "carbide fed to water" or "water fed to carbide type." In the United States the "carbide to water" type is the one used. The acetylene furnished is at a pressure of 4 to 6 inches of water column (app. $\frac{1}{4}$ lb./sq. in.). However, using this type of acetylene makes it necessary to use what is called an injector, or low-pressure type torch. The gas must be figuratively pulled along the pipe lines and into the torch in order

to be mixed with the oxygen. The oxygen, by passing through the injector, does this work. See Paragraph 37 for details of construction of the injector type torch.

The high pressure type of generator may be either of the two classifications mentioned above, but the acetylene is generated under pressures up to 15 lbs./sq. in.. This construction permits the use of the medium or equal pressure type torch. Acetylene generators *(Figure 26)* themselves are subjected to definite codes regarding their construction and locations where they may be placed, mounted, and used. They are very popular in the larger plants.

It is recommended that, when using these generators, the carbide and the water used be kept as pure as possible. Although ordinary tap water is sometimes used to produce acetylene, distilled water gives better results. The generators are always furnished with safety devices, which indicate any abnormal situation, such as being low in water, being low in carbide, or having too high a pressure. These safety devices should always be kept in the best of condition. A very common construction provides a basket for the carbide, suspended inside the floating dome which collects the acetylene gas. If the pressure tends to become too high, or if the consumption of the acetylene ceases, the dome rises and lifts the carbide above the water.

28. Pressure Regulator Principles

Inasmuch as the acetylene is commonly stored under a 250-lbs., sq. in. pressure, the oxygen under a 2000-lbs./sq. in. pressure, and because the pressures of the gas at the torch cannot exceed between 0-lb./sq. in. to 30 lbs./sq. in., it is necessary to use some mechanism to reduce the pressure. Two regulators are used; the acetylene regulator and the oxygen regulator. The mechanisms used for this purpose are called pressure regulators and are constructed in several different types. The purpose of the pressure regulator is as follows: (a) to reduce the high pressures to working pressures, and (b) to maintain very constant working pressures (constant volume). By working pressure is meant the pressure at which the gases are fed to the torch. Inasmuch as a pressure regulator is used for reducing and maintaining the pressures, gauges are mounted on this mechanism to inform the operator what these pressures are.

Three types of regulators that are in use are:

1. The nozzle-type regulator
2. The stem-type regulator
3. The two-stage regulator

The nozzle style, which is one of the most popular, is constructed and operated as explained in the next few paragraphs. *Figure 27.*

29. Pressure Regulators (Nozzle Type)

This regulator consists of a drop-forged or cast brass body (D) having fixed into the body a means whereby the regulator may be

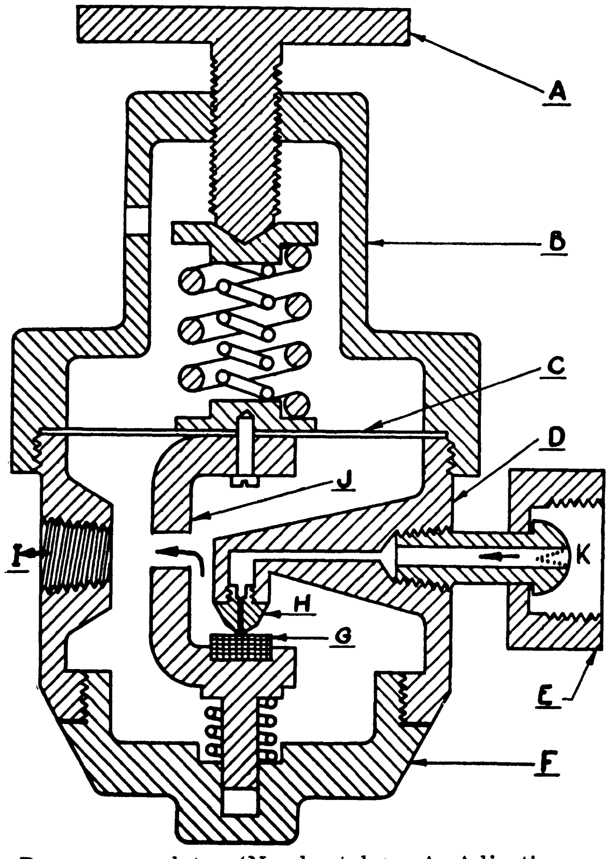


Figure 27. Pressure regulator (Nozzle style): A. Adjusting screw, B. Bonnet, C. Diaphragm, D. Body, E. Cylinder nut, F. Cap, G. Seat, H. Nozzle, I. Hose connection, J. Seat cage, K. Cylinder nipple and screen

fastened to the gas cylinder valve (K). It also has openings where the high-pressure gauges and low-pressure gauges may be threaded into it, and a third opening to release the regulated gas to the hose (I). The front of the regulator has a flexible wall called a diaphragm (C), which is sealed firmly to the regulator body. A spring is mounted between the outside of the diaphragm and the bonnet. (B) The pressure on the diaphragm is adjustable by means

of an adjusting screw threaded into the bonnet and pressing against the spring (A). An arm (J) is fastened to (or touches) the inside of the diaphragm, the arm curving down into the regulator body chamber and around to form a seat (G), which presses up against a nozzle (H) of the regulator. The opening is automatically controlled by the diaphragm to allow the gases to come from the cylinder when needed. The line that leads up to the nozzle comes from the cylinder; and to this line is fastened the high-pressure gauge. A fine mesh screen is commonly located in this line to keep dirt from entering, and injuring the regulator. The arm which comes from the diaphragm is backed by a spring, (or is fastened to the diaphragm) which continually tends to push the seat of the valve firmly against the nozzle to stop the gas flow.

If the adjusting screw in the body is turned "in" (clockwise), the heavy spring on the outside of the diaphragm will press the arm against the body spring, moving the seat away from the nozzle, and allowing some gas to come from the cylinder. As this gas enters the regulator body, it tends to build up a pressure in the body. This pressure will push the diaphragm out against the bonnet spring.

When the gas, which was released into the regulator, goes up the hose to the torch, the pressure will tend to drop. This will allow the diaphragm to move in, again opening up the valve and allowing more gas to come into the regulator body. The pressure in the body cannot increase or decrease from a certain setting because of this compensating action. A constant pressure, therefore, is maintained in the regulator body, independent of what the pressure is inside the cylinder. At a particular setting of the adjusting screw (A), a specific and constant pressure will be maintained in the body as long as the cylinder valve is open. If the adjusting screw (A) is turned in, this pressure will increase somewhat, and then stay constant at the higher pressure. If the adjusting screw (A) is turned out, the pressure will decrease somewhat and then stay constant. If the adjusting screw (A) is turned all the way out, it will stop the flow of gas from the cylinder completely.

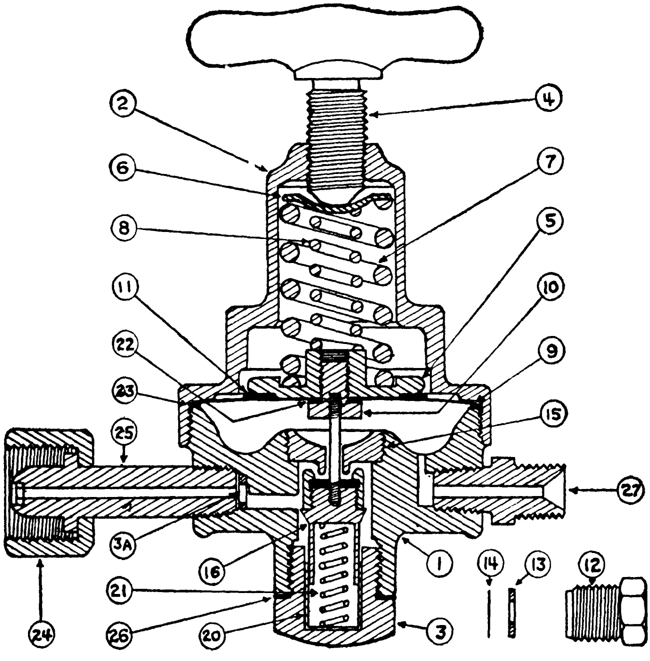
These regulators come in various gas-flow capacities and nozzle orifice size; the diaphragm size and the spring size are changed according to the volume of gas desired. Master regulators and line regulators come under the latter classification.

The springs are made of a good grade of spring steel, while the diaphragm is made of brass (phosphor bronze), sheet spring steel, or rubber. These diaphragms were formerly soldered to the regu-

lator body, but modern practice is to seal this joint by means of clamping it between the body and the bonnet. The nozzle is made of a finely machined bronze, while the seat is made of various materials such as (Buttermilk) Casein glue blocks, hard rubber, or fiber.

30. Pressure Regulators (Stem or Pin Type)

The stem-type regulator works on the same principle as the nozzle type, but instead of using a nozzle and seat, it uses a poppet



34— 1	Body	34— 6DC	Spring Button	34—15	Nozzle
34— 2	Bonnet—Brass	34— 7	Tension Spring	34—16	Seat Assembly
34— 2DC	Bonnet—Die Cast	34— 8	Tension Spring	34—20	Seat Pilot
34— 3	Back Cap—Brass	34— 9	Diaphragm	34—21	Seat Spring
34— 3A	Inlet Screen	34—10	Yoke	34—22	Yoke Washer
34— 4	Adjusting Screw	34—11	Diaph. Plate Washer	34—23	Diaphragm Washer
34— 4DC	Adjusting Screw	34—12	Safety Bushing	34—24	Inlet Nut
34— 5	Diaphragm Plate	34—13	Safety Washer	34—25	Inlet
34— 6	Spring Button	34—14	Safety Disc	34—26	Back Cap Washer

Figure 28. A stem type welding pressure regulator
(Courtesy of: Dockson Corporation)

valve and seat, or stem and seat. *Figure 28.* Notice that the high pressure gas enters the rear chamber, while the forward chamber diaphragm controls the torch gas pressure. The construction is such that the high pressure tends to force the valve closed. The valve stem, therefore, does not need to be fastened to the diaphragm. These regulators are commonly used where high volume capacity is essential. (Manifolds, regulators, etc.)

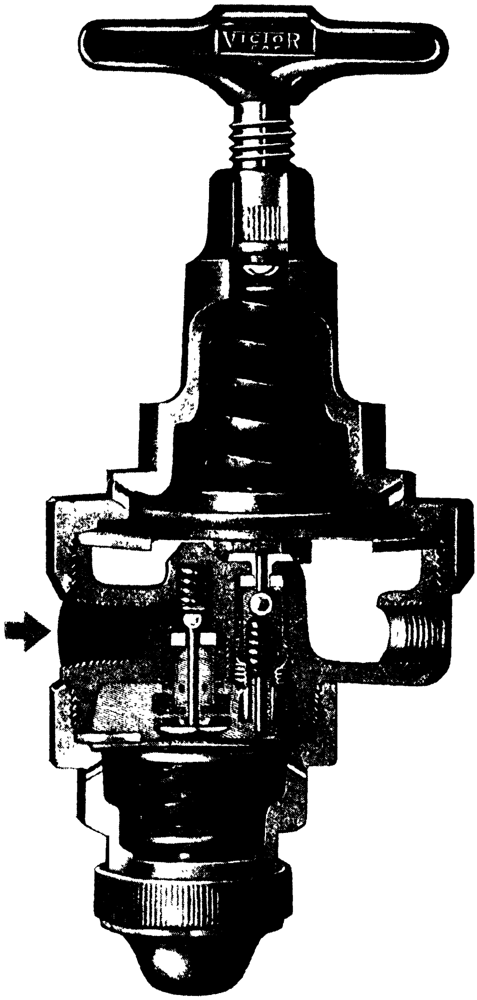


Figure 29. The two stage regulator provides two diaphragms, two needles, and two seats. The first stage reduces the high gas pressure (red) as it comes from the cylinder to some intermediate pressure (orange). The second stage is the low pressure stage which reduces the intermediate pressure (orange) to some constant pressure needed by the torch (yellow). The large wing type adjustment screw controls the low pressure to the torch only

Courtesy of: Victor Equipment Company)

The materials of construction are similar to the nozzle type. The seat is constructed of the same material, while the stem (pin) is usually made of stainless steel. The stem and seat are designed to enable the complete assembly to be removed as a cage, permitting easy servicing.

31. Pressure Regulators (Two-Stage Type)

The two-stage regulator may be considered as two regulators in one. The high pressure is reduced and regulated to an intermediate pressure, which is then reduced and regulated to the final torch gas pressure.

The first stage is usually a "fixed" stage, that is, the pressure in the intermediate chamber is kept constant by means of a non-adjustable diaphragm. In case of the oxygen, two-stage regulator, this pressure is 200 lbs./sq. in., whereas in the acetylene, two-stage regulator it is kept at 50 lbs./sq. in. *Figure 29.* This latter regulator will provide a more constant torch pressure, especially when large volumes of gas are being consumed.

All of these regulators are provided with safety devices, which protect the diaphragm and other operating mechanisms from severe abuse and even destruction. The device usually consists of bursting discs, connected to the low-pressure chamber of the diaphragm. The disc will burst at a pressure between 100 lbs. per sq. in. and 200 lbs. per sq. in. which is below the pressure at which the diaphragm will burst.

32. Safety in Handling Regulators

A. Never use oil on a regulator.

B. Be sure the regulator adjustment is turned all the way out before opening the cylinder.

C. Always open the cylinder valves very slowly. This precaution helps preserve the gauge accuracy, and forms a safety measure in case the regulator leaks.

D. Use only soap or glycerine to lubricate the regulator screw.

E. Never interchange the oxygen regulators for acetylene regulators, or conversely.

33. Welding Gauges

As mentioned in a previous paragraph, the gauges are mounted on the regulators. The high pressure gauge is connected into the regulator between the regulator nozzle and the cylinder valve; it registers the cylinder pressure whenever the cylinder valve is

opened. The low pressure gauge is connected into the diaphragm chamber of the regulator, and registers the pressure of the gas used for welding. The gauges are built with gears and springs similar to a pocket watch; being of this delicate construction they must be handled accordingly.

The main parts of a gauge are externally: the fitting whereby the gauge is fastened into the regulator, the bodycase of the gauge,

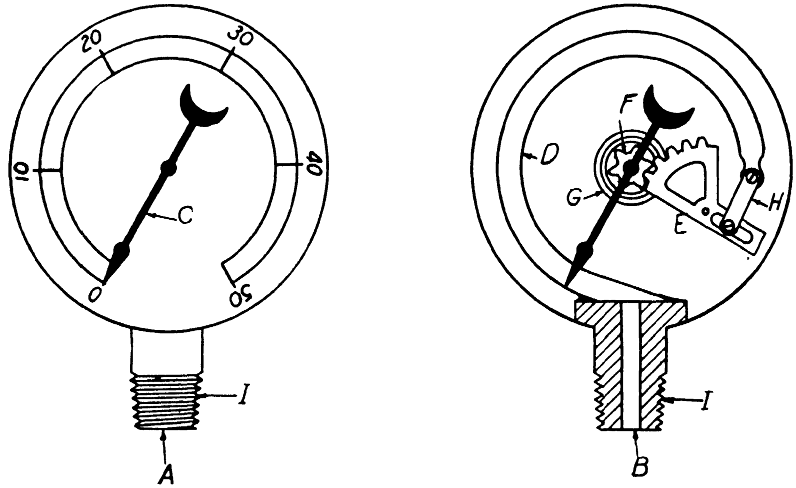


Figure 30. Pressure gauges: A. External view, B. Internal view, C. Needle, D. Bourdon tube, E. Gear sector, F. Pinion gear, G. Hair spring, H. Adjustable link, for calibrating, I. ¼″ pipe threads

the glass crystal, the bezel, the dial, and the needle; internally, the Bourdon tube, the gear sector, and the watch spring. The basic construction of the gauge is a flattened semi-circular piece of copper tube, sealed at one end and with the other end fastened and soldered to the gauge fitting. The Bourdon tube, when the pressure is changed on the inside, tends to bend. The more the pressure increases, the more the tube tends to straighten and conversely. The sealed end of the tube is fastened by means of a lever to a gear sector, and the gear sector in turn is in mesh with a gear which drives the gauge needle. A watch spring is fastened to the needle shaft and is used to maintain accurate calibration. The parts are made of brass and silver soldered. The bearings and the watch spring are of a rather delicate construction, the gears and bearings being made of small brass parts, whereas, the watch spring is a very fine steel spring. *Figure 30.*

The fitting, by which the gauge is fastened to the regulator, is usually a ¼″ male pipe thread. A glass crystal is used and is fastened

to the body by means of a large-threaded, clamp ring (called a bezel). The gauges come in various sizes, the 2½″, 3″, and 3½″ diameter dials being the most popular. The calibration of the gauges depends entirely upon the pressure to be used, and the usual recommendation is that a gauge be obtained with a dial indication of at least 50% more than the highest pressure to be used.

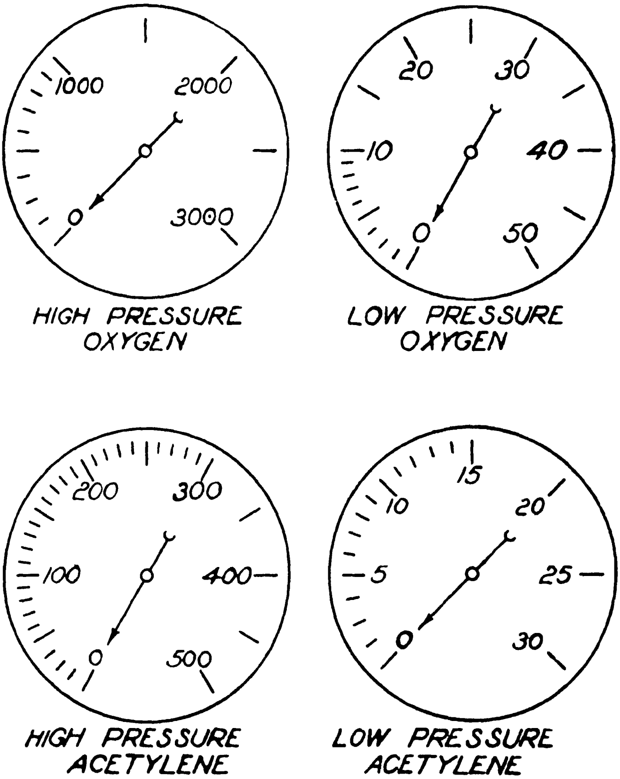


Figure 31. Dial readings

The oxygen high pressure gauge usually has a 3½″ diameter dial and is calibrated from 0 lbs./sq. in. to 3,000 lbs./sq. in. There are two scales on the high pressure oxygen gauge; one is the pressure scale mentioned above, while another scale is calibrated in cubic feet, and indicates the amount of gas left in the cylinder under various pressures which are indicated on the dial. This type of scale is feasible for the oxygen because the oxygen is stored under direct pressure, and the amount of gas in the pressure cylinder is proportional to this pressure.

The high pressure acetylene gauge is of the 3″ diameter size and is calibrated up to 400 lbs./sq. in. or 500 lbs./sq. in.

The low pressure acetylene gauge is usually of the 2½″ dial size and is calibrated from 0 to 30 lbs./sq. in. or 50 lbs./sq. in., although many gauges are only calibrated up to 15 pounds, leaving the space from 15 to 50 lbs./sq. in. blank.

The oxygen low pressure gauge has a variety of dial calibrations. For light welding, the dial (2½″) is calibrated up to 50 lbs./sq. in., but for heavy welding and for cutting, the gauge may read as high as 200, 400, or even 1000 lbs./sq. in. The diameter of the cutting gauge is usually 3″. *Figure 31.*

Some rules to be followed when handling gauges are:

1. Never have the regulator adjusting screw turned in when opening the cylinders, as the pressure will rupture the Bourdon tube and permanently wreck the low pressure gauges; it might also injure the regulator.
2. When opening the cylinder valve, or when turning the adjusting screw in on the regulator, *turn these stems slowly* because, if the pressures are allowed to enter the gauges too suddenly, even though the pressure is not excessive, it will strain the mechanism of the gauge and eventually destroy its accuracy.
3. The maximum pressure to be used in a gauge should never exceed ½ to ⅔ of the calibration of the dial, meaning that if the gauge is calibrated up to 300 lbs./sq. in., a 200 lbs./sq. in. reading should never be exceeded.
4. White lead, or preferably a paste made of glycerine and litharge, should be used for sealing the threads when the gauge is fastened into the regulator.

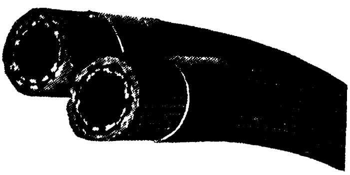


Figure 32. Cross sectional view of a welding hose
(Courtesy of: Linde Air Products Company)

34. Welding Hose

For most oxygen-acetylene welding, a flexible medium must be used to carry the gases from the cylinders to the torch. The popular means used is reinforced rubber hose. This hose must be flexible and strong, and the gases must have no deteriorating effect on the materials of construction. The hose is built of three principal parts:

the inner lining which is composed of a very good grade of gum rubber; this in turn is surrounded by four or five layers of rubber-impregnated fabric, while the outside cover, or wearing cover, is made of a colored vulcanized rubber, plain, or ribbed, to furnish a long wearing surface. *Figure 32.* The hose is manufactured in three standard colors; black, green, and red. The use of these colors is not standardized, but the red is usually used for the acetylene hose while either the green or the black is used for the oxygen hose. The hose is specified according to its inside diameter and it comes

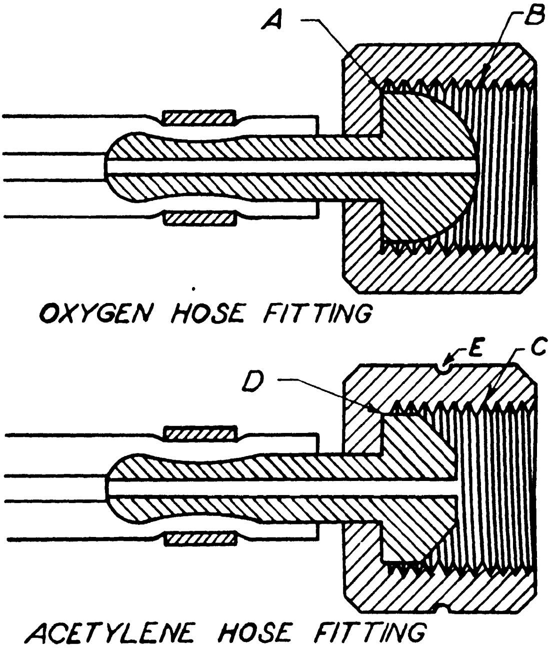


Figure 33. Hose nipple and fittings: A. Oxygen nipple (round nose), B. Oxygen nut (right hand threads), C. Acetylene nut (left hand threads), D. Acetylene nipple (straight taper), E. Acetylene nut (grooved on the periphery)

in several sizes ranging from $\frac{3}{16}''$, $\frac{1}{4}''$, and $\frac{5}{16}''$. The size to be used depends upon the size of the torch and the length of the hose to be used.

The hose is never to be used alternately, carrying first one gas and then another gas. If oxygen were to pass down an old acetylene hose, a combustible mixture might form. To prevent this, special precautions are used when fastening the hose to the regulators and torch. The hose is clamped to a nipple by means of a hose, the regulator or torch by means of a nut. The nut and fitting have right-hand and threads, if they are to be used with oxygen, and the

nut is marked OXY. If the fitting and nut are for acetylene, the threads are left-hand and the nut is marked ACE; it also has a groove machine around the periphery of the nut. The oxygen nipple sometimes uses a rounded nose, while the acetylene uses a straight taper as a sealing surface. *Figure 33.*

The hose must be carefully handled to prevent accidents. It should not be allowed to come in contact with any flame or hot metal. Care should be taken that the hose is not kinked sharply, as this might crack the fabric and permit the pressure to burst the hose. A kink will also hinder the gas flow. When the equipment is not being used, the hose should be hung away from the floor, and away from other things that might injure it. When welding, the hose should be protected from falling articles and from being stepped on, as this might crack the fabric.

35. Types of Oxy-Acetylene Torches

Two types of torches (sometimes called blowpipes) are in use at the present time. These two types come in a variety of sizes and designs. They are:

(a) The welding torch
(b) The cutting torch

These torches are somewhat the same in their construction, the cutting torch being a welding torch with an extra oxygen outlet. The welding torch may be further subdivided into:

(a) Equal pressure type (medium pressure type)
(b) The injector type

36. The Equal Pressure Type Welding Torch

The welding torch is that part of the equipment in which the gases are mixed, and at the tip of which the gases are burned. It consists of four main parts:

1. The hand valves
2. The mixing chamber
3. The body
4. The tip

The equal pressure torch is used with cylinder gases, while the injector torch is used with a low-pressure, acetylene generator (factories, etc.). The equal-pressure, torch construction necessitates that each gas has enough pressure to force itself into the mixing chamber, whereas the injector type torch uses the oxygen velocity to induce the acetylene into the mixing chamber. The torches are

usually made of brass, and the various parts are threaded and silver-soldered together.

The equal pressure torch, being used with cylinder gases, is therefore more universally used. This torch is constructed and operated as explained in the next few paragraphs. *Figure 34.* The hand valves are located at the point where the hose is attached to the torch and are brass, needle-type valves. They are packed with asbestos twine. These hand, shut-off valves are usually used only for shutting the gas off and turning it on; however, some operators use these valves to throttle (final adjustment) the gases being fed to the torch.

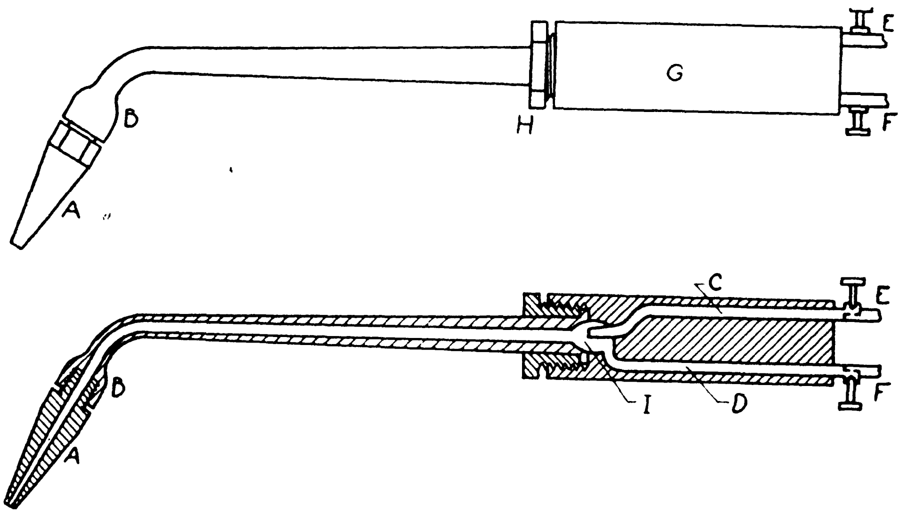


Figure 34. Equal pressure torch

The mixing chamber is usually located inside of the torch body, although some of the older designs incorporate the mixing chamber in the tip, or as a part of the tip. The gases are fed to this chamber through two brass tubes leading from the hand valves. The size and design of the mixing chamber depends upon the size of the torch. It may be mentioned here that the size and shapes of the holes and chambers should never be altered, nor should the parts be abused if economy and good welds are desired. The gases after being mixed are fed through the barrel of the body to the point, or the tip (new models), where combustion takes place. The orifice, or hole drilled in the tip, must be accurately sized, and a different sized hole is used for each size or number tip. The tip sizes, or numbers, vary from No. 0 up to No. 15. Approximately

as many pounds pressure each of oxygen and acetylene must be used as the number of the tip. *Figure 34.* Some companies use a style number before the size number as 60 up to 612, but the first number stands for the style or model number, and may be neglected when determining the size of the tip. All the various parts must be handled with reasonable care to insure a long, useful life.

Tip No.	Oxygen Pressure	Oxygen Cu.Ft./Hr.	Acetylene Pressure	Acetylene Cu.Ft./Hr.	Speed Ft./Hr.	Metal Thickness
1	1	.8	1	.8	....	....
2	2	2.0	2	2.0	20	1/32
3	3	4.	3	4.0	16	1/16
4	4	7.	4	7.0	14	3/32
5	5	9.	5	9.0	12	1/8
6	6	17.	6	17.0	10	3/16
7	7	23.	7	23.0	9	1/4
8	8	31.	8	31.0	7.5	5/16
9	9	40.	9	39.0	6	3/8
10	10	47.	10	46.0	4.5	7/16
11	11	59.	11	58.0	3.5	1/2
12	12	70.	12	69.0	3.25	9/16
13	13	77.	13	75.0	3.0	5/8
14	14	95.	14	93.0	2.5	3/4
15	15	107.	15	105.0	....	Extra heavy

Figure 35. Oxygen and Acetylene pressures: These values are only the average values and the welder should consult the specific torch specifications

37. Injector Type Welding Torch

Whenever low pressure acetylene is used (approximately 1/4 lb./sq. in. gauge), a different type of torch must be used. The construction must be such that the oxygen will suck the acetylene out of its line and into the mixing chamber. Other than the mixing chamber design, the materials of construction of the injector-type torch are exactly similar to the equal pressure type.

A recent innovation in tip construction for these torches is to use a bronze tip sweated into a steel hexagon and seat. This construction gives the tip a much longer life than was formerly possible when they were made of bronze or brass because of the softer bronze threads and hexagon.

The principle of the mixing chamber of the injector torch is based upon the Venturi principle. The oxygen is injected into a chamber at a high velocity; as it leaves the nozzle and passes through the chamber and down the tube leading to the tip, it creates

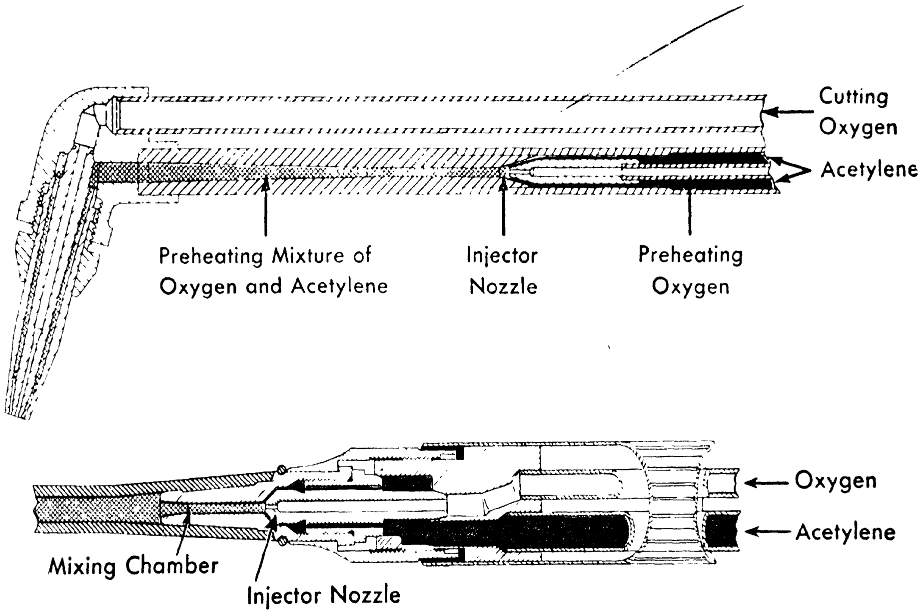


Figure 36. An injection type cutting torch (top), and a welding torch (bottom). The acetylene (red) is induced (drawn) into the mixing chambers by the pulling action (suction) of the oxygen (yellow) jet. The mixture of oxygen, and acetylene are shown as checked red and white. These injector torches are particularly adaptable for use with acetylene generators which operate under low pressure

(Courtesy of: Linde Air Products Company)

a partial vacuum in the chamber. The acetylene is piped up to this chamber, and when the low pressure is created by the velocity of the oxygen, the acetylene is sucked into the chamber and is mixed into the oxygen stream. The mixture then goes down the barrel tube, and combustion takes place at the end of the tip. *Figure 36.* The torch uses an oxygen pressure, considerably in excess of that used for the equal-pressure type of torch.

The cutting torch construction and operation will be discussed in *Chapter 13.*

38. Safety in Handling Torches

Some pointers about the care of torches to insure long life and safety are as follows:

1. Never put a cold tip in a hot torch.
2. Never use pliers on any torch part; use the proper sized wrenches.
3. Never interchange the tips with those of other torches.
4. Never scrape the point of the tip on an abrasive, as this will permanently injure the orifice. Use a block of wood or leather.
5. Never use a hard wire to clean out the tip orifice.
6. Be very careful when reaming a tip with a tip reamer, or the hole will be made too large.
7. Never lay the torch down when it is burning.
8. Never use oil on any part of the torch; use soap or glycerine.
9. Never use pliers on the hand valves; close them firmly with the fingers.
10. Never allow a torch to backfire continually. Find the trouble before continuing to use it.
11. The equipment stand should provide a place to hang the torch conveniently.

39. Welding Goggles and Protective Devices

The welding flame and the molten puddle, because of their high temperature and concentration, emit a large quantity of ultraviolet and infra-red rays which cannot be watched safely with the naked eye any closer than 15 to 20 feet. Sparks flying from the weld may also injure the eye. The welder, who necessarily must stand very close to the flame and must watch it closely, has to protect his eyes from these rays and sparks. A special goggle is used to do this. These goggles frame the eyes completely, allowing light to enter only through the lens, which is the double style. An outer lens of flat glass ($1/16''$ to $3/64''$ thick) is used to protect the inner safety

lens from injury, sparks, etc. The inner glass is a very expensive, especially treated glass of a green or amber shade which has the property of excluding practically all of the harmful rays. These special lenses usually allow only the green, orange, and yellow rays to pass.

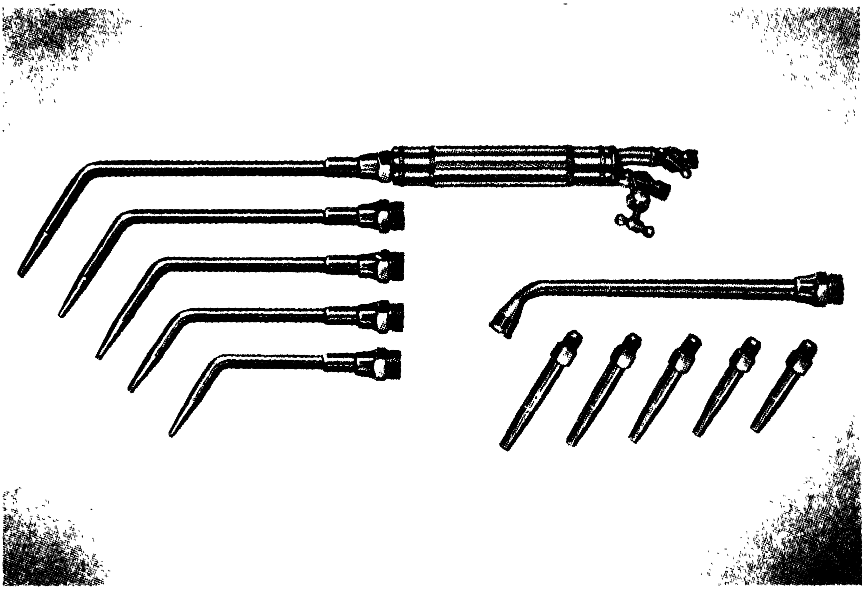


Figure 36A. Torch with one piece torch tube and tip or with the tips detachable from the torch tube
(Courtesy of: Dockson Corporation)

The goggles should be ventilated; they should have an adjustable nose bridge, and the elastic for fastening the goggles around the head should be easily adjustable. Special care must be taken that the lens holders should not become loose because one colored lens costs as much as $1.00. The lens diameter is usually standard at 50 m.m. although some older models use 46 m.m. lens, and they come in various depths of color, No. 1 through No. 12. The No. 4 to No. 6 is the average light welding shade, while No. 12 is used for arc welding. The color preference is an individual choice because either color is just as efficient as the other. *Figure 37.*

Another accessory of a welder is some form of gloves to protect his hands, especially when applying a short filler rod. These gloves are best when they are made of leather and have a tight cuff extending over the sleeve of the work clothes.

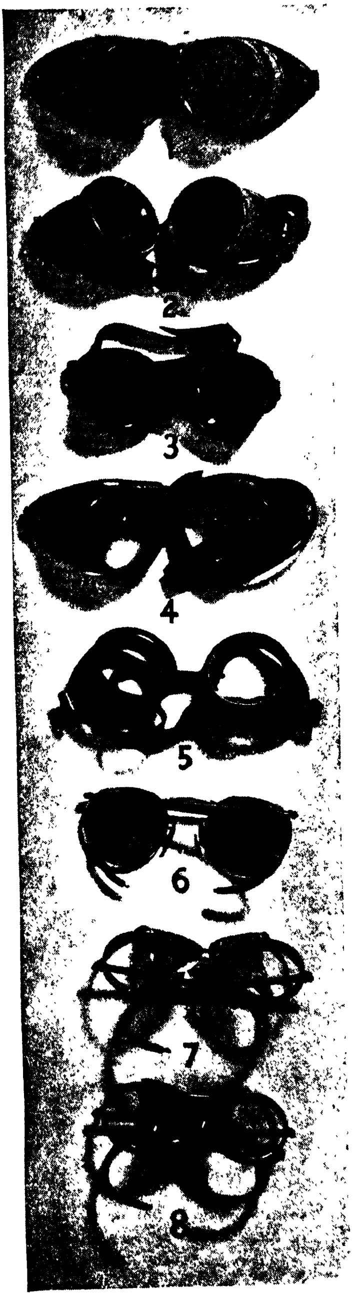


Figure 37. Welding goggles: *1*, *2*, *3*, and *4* are welding goggles; *5*, *6*, *7*, and *8* are grinding goggles
(Courtesy of: Victor Equipment Company)

40. Torch Lighters

Matches, or burning paper, are not recommended for lighting a welding torch. A flint and steel lighter is considered the best portable lighter. *Figure 38.* It gives a very local ignition and extinguishes itself immediately. Also, the spark can only be obtained purposely, and the instrument is not combustible in itself.

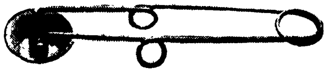


Figure 38. Flint and steel lighter
(Courtesy of: Linde Air Products Company)

Many places which require a number of welding stations use a pilot light, using either city gas or acetylene. The city gas is piped to an outlet near the welding station, and a small flame is left burning continuously. The flame outlet should be located overhead where it will not have any chance of igniting anything on the living level of the room. The acetylene pilot light may be either of two constructions; one leaves a very small acetylene flame burning at the torch tip when the torch valves are turned off (not the cylinder

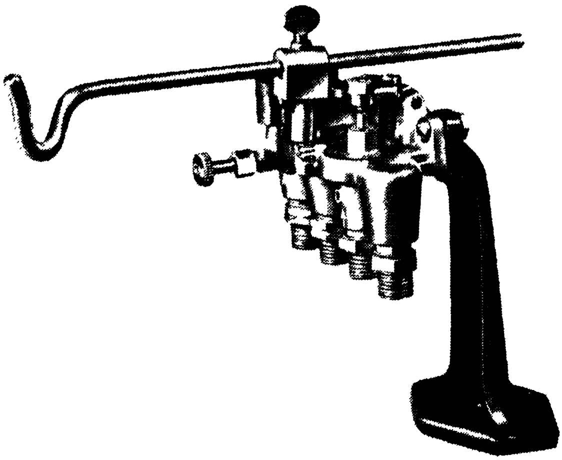


Figure 38A. Gas economizer
(Courtesy of: National Cylinder Gas Company)

valves); when the operator turns the acetylene on, it immediately ignites. The other type is more of an economizer than lighter. It consists of a mechanism through which the oxygen and acetylene are first led before being passed to the torch. The mechanism is also used as the torch holder when the torch is not being used. Before the torch is placed in this holder, it is lighted and adjusted.

When put in the holder, it presses a lever which turns off both the oxygen and acetylene, leaving a little acetylene burning at a special outlet, or pilot light. When the torch is lifted from this holder, it ignites itself and is ready to be used for welding. The device saves considerable gas and also increases the safety of the equipment, as the torch cannot be laid aside and still continue to burn. *Figure 38A.* Another method of igniting the gas, which is not in extensive use, is to use a high-tension, electric spark from a transformer; still another method is to connect one lead of a 30 volt circuit to the torch and the other lead to the welding table. The operator turns on the acetylene and touches the tip to the bench. The spark resulting from the closing of the electrical circuit will ignite the gas.

41. Oxy-Acetylene Welding Supplies

The welding procedure in order to be performed correctly needs many special products or supplies. These supplies must be of good quality; some must be of fresh stock, and the right supplies should be used for each particular welding torch. The more common supplies needed for welding are as follows:

1. Welding Gases:
   a. Oxygen
   b. Acetylene
   c. Hydrogen
   d. City gas
   e. Propane
2. Filler Rod (Welding Rod)
   a. Steel
   b. Cast iron
   c. Brazing
   d. Aluminum
   e. Special
   (1) Silver solder rod (2) White metal rod (3) Stellite and stoodite
3. Fluxes
   a. Welding cast iron
   b. Brazing
   c. Aluminum welding
   d. Silver soldering
   e. Special
   f. Brazing cast iron
   g. Stainless steel welding
4. Firebrick
5. Carbon paste and forms
6. Asbestos packing
7. Glycerine
8. White lead or litharge

42. Welding Fuel Gases

The handling and purchasing of the two gases, acetylene and oxygen, have already been explained as a part of the welding equipment in the first part of this chapter.

Hydrogen is sometimes used with oxygen instead of acetylene, but the resultant flame does not have so high a temperature as the oxv-acetylene flame. The gas is obtainable in cylinders similar to

oxygen cylinders, except that the cylinders use left-hand threads on the fittings, and they are painted a different color. The cylinder is rented to the purchaser of the hydrogen for a small charge, but remains the property of the manufacturers of the hydrogen.

Propane is a by-product of gasoline manufacture, and the cylinders are labeled and colored characteristically for propane (silver and orange). Propane, however, differs from the other gases in that when stored under a pressure in the cylinder, it condenses and forms a liquid. Therefore the cylinder is full of liquid, and must always remain upright when being used. Propane is used for pre-heating large metal parts before they are welded, and is also used for cutting.

City gas is used for pilot lights and for pre-heating, and may be either of the natural or artificial type. The gas should be protected by a water-seal, blow-back valve to keep the gas from back-firing into the main pipe.

43. Filler Rods

Filler rods are used to build up the welded joint in order that the joint may be of the same strength as the parent metal. A good general rule to follow when choosing filler rods for a particular task is to use the same metal for the filler rod as is in the parent metal. Another general rule for all filler rods is that they should be as free from impurities as is commercially possible.

Steel welding rods come in various diameters and in one standard length. They are purchasable in 50 lb. bundles. The rods are usually copper colored because of their protective coating of copper plate to keep them from rusting. If a copper plate is not used, the rods must be coated with grease to protect them from rust. The common steel rod is a pure Swedish steel, having a very low carbon content. .02 carbon to .04 carbon. The sulphur, phosphorus, rust, and impurity content must be an absolute minimum. Separate racks, or bins, must be constructed to file the rods as to diameter, grade, new rods, and used rods. Old rods (short pieces) may be used by welding them together to form longer pieces.

Steel rod quality must be high, or very unsatisfactory welds will result. The rod should not sparkle when melted by a neutral flame and should flow freely.

Some common specifications of steel filler rods for welding cold drawn steel and other low carbon steels are as follows:

Carbon	.04%	maximum
Manganese	14%	"

Phosphorus and sulphur.....	.04%	"
Silicon	.08%	"

The welding rod is ordered by the pound; it is usually packed in 50-lb. bundles and comes in 36″ lengths. No special, high-carbon rods are available for tool steel welding or other high strength steel, inasmuch as they cannot be satisfactorily welded with steel rod. One should braze high speed steels. It has been reported that welding spring steel with spring wire in a very carefully adjusted flame will produce satisfactory welds.

Cast iron filler rod is a high grade cast bar having either a round or square cross-section. The rod must be free from dirt, rust, slag, and other impurities. A flux must be used with this rod. Brazing filler rod is used for hard soldering and brazing. The rod may be made either of brass (copper and zinc), or bronze (copper and tin). Usually, however, the bronze is preferred. A high quality and purity are again desirable to obtain good results.

Aluminum filler rod is obtainable in the cast and wire form, these being used for cast aluminum and sheet aluminum respectively. The filler rod must be of very high purity and must contain no oxides. The cast filler rod is ¼″ x ¼″ square, and 18″ long, while the rolled wire is ⅛″ diameter and is supplied in rolls of 50-lb. to 75-lb. per roll.

44. Welding Fluxes

Most of the non-ferrous welds and cast-iron welds necessitate the use of a chemical cleaner, reducer, and protector called a flux. The flux is applied to the weld to prevent oxidation and other forms of corrosion; it chemically cleans the metal to promote a better weld. The different fluxes needed are:

1. Cast-iron flux
2. Brazing flux
    a. Steel
    b. Cast-iron
3. Aluminum Flux
4. Silver-soldering flux
5. Soft solder flux

Cast iron flux is usually reddish in color and is obtainable in 1-lb. cans. The flux consists of a mixture of iron oxide, carbonate of soda, and bicarbonate of soda.

The type of brazing flux depends upon the kind cf work to be hard soldered or brazed. Steel is brazed by using a white flux, consisting of chlorides. Borax, fresh and chemically pure (C.P.), is

an old and reliable flux for brazing, copper welding, and silver soldering. The different kinds of brazing flux are: (1) steel brazing, (2) cast iron brazing, (3) cast steel brazing, (4) copper. Aluminum flux, a white powdery substance usually retailed in sealed bottles, is used for both cast and rolled aluminum. The flux is usually mixed into a paste by adding water, and then applied to the joints to be welded and to the filler rod. The flux must be kept sealed to retain its good qualities, and a fresh flux is always recommended. The contents of a typical aluminum flux (Dockson's) are as follows:

Sodium Chloride	6.5%
Sodium Sulphate	4.0%
Lithium Chloride	23.5%
Potassium Chloride	56.0%
Cryolite Chloride	10.0%

Some other fluxes used extensively for welding are silver soldering flux, monel metal flux, stainless steel flux, stellite flux, stoodite flux, and white metal.

A general rule to follow for the use of fluxes is to choose the flux specifically labeled as the correct flux for that type of metal. All of the above fluxes may be obtained in any quantity from any of the larger welding supply houses.

45. Fire Brick

Firebrick is used to form welding table tops, and is used to build forms around articles for preheating, annealing, and normalizing. The brick is usually 8¾″ x 4½″ x 2½″ and is labeled "fire-proof brick."

46. Carbon and Asbestos

Carbon packing is used to back up welds to prevent the molten metal from going out of control. It is obtainable in standard shapes and either in paste or in loose powder form.

Asbestos packing is used to protect parts of a metal, which is being welded, from overheating especially from radiated heat. A wall of asbestos is built around the weld and keeps the heat from spreading. It is obtainable in pound bottles and it is a grayish spongy mass. It is moistened to enable forming it into the shape desired.

47. Glycerine, White Lead, and Litharge

The threaded joints in the brass parts of an oxy-acetylene station are sometimes pipe threads. To seal these threads thoroughly, one may prepare a thick paste of glycerine and litharge (red lead powder), or use white lead paste. The former makes a much better seal, but once the mixture has "set," the joint is almost impossible to break, or open. The white lead paste is therefore recommended for those threaded joints that may occasionally have to be disconnected.

Glycerine may also be used as a lubricant for regulator adjusting screws and valves. *Oil must never be used.*

48. Review Questions

1. What is a safety plug on an oxygen cylinder?
2. What is a safety plug on an acetylene cylinder?
3. What threads are used on acetylene fittings?
4. What threads are used on oxygen fittings?
5. Of what are pressure-regulator diaphragms made?
6. Why isn't oil used on welding fittings?
7. What is used to lubricate welding equipment parts?
8. Why is the welding hose colored?
9. What calibration gauge is used for the low pressure oxygen when ordinary welding is being done?
10. How many types of welding torches are used?
11. What is a two-stage regulator?
12. What oxygen pressure and acetylene pressure are used with a No. 4 tip on an equal pressure torch?
13. What protection do welding goggles provide?
14. What are the two types of torches?
15. Why is a flux necessary for certain types of welding?
16. Is it necessary to use a flux when welding mild steel? Why?
17. Describe three specific applications of carbon paste.
18. What is the size of the regulation firebrick?
19. Name some uses for asbestos sheet and packing.
20. Why aren't matches recommended for lighting welding torches?

CHAPTER III

ELECTRIC WELDING THEORY AND PRACTICE

This text will be used almost exclusively to explain the practice of electric arc-welding, using metallic electrodes; however, the various kinds of electric welding will be defined and explained in this chapter.

49. History of Electric Welding

Electric welding has followed almost the same development as oxygen and acetylene welding chronologically. The theory of electric welding was known many years ago, but it was not until electricity in large quantities was available that the various types could be experimented with extensively, and developed. It, therefore, necessitated the introduction of the electric dynamo, developed in 1877, to perfect all the methods that are known at present. Since that time the development has been steady, and in the last 10 to 15 years, various automatic electric welding machines have become very numerous. Of the total quantity of welding done, the different types of electric welding accomplish by far the most of it.

Arc welding was first made use of in the year 1881 to connect the various parts of storage battery plates together; the method was perfected by DeMeritens. In 1886 resistance welding was first used on a large scale to fuse various metals together; the method used was developed by Elihu H. Thompson. The method used by Thompson is now called butt welding. It consists of placing the metals in large clamps, bringing the edges together, and at the same time passing a heavy current through the two metals. The resistance at the joint produces a very high heat, and the pressure fuses the two pieces together. The method is still called the Thompson method. Prior to all these commercial uses of the arc weld, cases have been known where lightning striking in certain spots fused metals together, and the theory of the arc weld was therefore known a considerable length of time before it was actually used.

The use of arc welding depended naturally upon the development of electricity, and dynamos or generators were not developed until the 1880's. The advancement of arc welding came hand-in-hand with the improvement of motors and generators. Many instances are recorded in which the old-fashioned, or original dynamos threw arcs in the dynamo, fusing some parts of the mechanism together.

The first actual arc welding, meaning the melting of metal by means of electrodes and thus fusing them together, was developed by Bernardoz, who created a mechanism using carbon electrode. Producing an arc between the carbon and metals melts the edges to be welded together, thus performing the weld.

This method was patented, but did not make much headway in the commercial world because the weld produced was found to be brittle and easily broken. Better development of carbon electrodes, making them more consistent and pure, improved this method of welding tremendously; and even today, although it is not the most popular form, it can produce welds of nearly the same quality as other types. This carbon-arc type of welding was developed in St. Petersburg, Russia, in 1880. The arc form of welding, using the metallic electrodes, was discovered by Slavinoff in 1895, but he had very little success in the method because of the use of bare metal electrodes. However, when Kielberg, a Swedish inventor, developed the flux electrode in 1905, the success of the metallic electrode was assured. Slavinoff, who invented the original method, was responsible for introducing this method to the United States. From this point on, the new development took place slowly, the major development being in the producing of portable machines and of automatic welding machines.

At the present time many of the old fabricated methods have been discarded in favor of the auto-electric arc welding methods. Shortly after 1905, a slightly different, arc-welding process was developed, called the LaGrange-Hoho process. This process consists of connecting the article to be welded to one machine and immersing the other end in a bath of water. When the current is started, the gas formed is so intense that the part to be welded becomes red hot, it is also protected from oxidizing by the gas bubbles surrounding it. It is then withdrawn from the water bath and welded in a manner similar to the blacksmith type of welding.

50. Principles of Electric Arc Welding

There are two basic principles of the electric weld. The one that will be studied most frequently in this book is the electric arc principle. This method is based upon the fact that as the electricity passes through an air gap from one electric conductor to another, it produces very intense and concentrated heat. The temperature of the spark, or the arc, jumping between the two conductors, is approximately 6500° to 7000° F. This theory is a basis of the following arc welding methods:

a. carbon arc welding
b. metallic electrode arc welding
c. atomic-hydrogen welding
d. electric arc cutting

The second basic theory for electric welding is the fundamental principle that when electricity passes through a substance which resist its flow, heat is developed. This is called electric resistance welding. Example: If two pieces of steel were brought together, and their edges touched while a current flowed from one piece to the other, the slight resistance at their joint would produce a high temperature and a quantity of heat. This heat would melt the edges

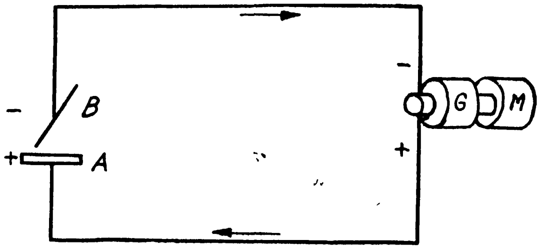


Figure 39. Metallic arc circuit: A. Metal being welded, B. Electrodes, G. Generator, M. Motor

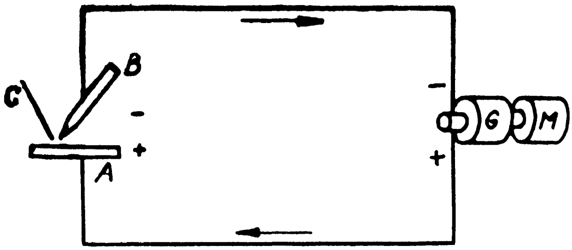


Figure 40. Carbon arc circuit: A. Work being welded, B. Carbon electrode, C. Filler metal, G. Generator, M. Motor

of the two pieces of metal, permitting fusion and a weld. The different types of electric-resistance welding based on this theory are:

a. Spot welding
b. Butt welding
c. Projection welding
d. Seam welding

The previous paragraph has tabulated the various kinds of electric welding, the meaning of the terms used being as follows:

a. The metallic electrode arc method of welding consists of producing an arc between the metal to be welded and the metal to be added to the parent metal (metal electrode). This is usually done by having the operator hold the metallic electrode and with it strike an arc on the parent metal. *Figure 39.* The arc produced will melt a puddle in the parent metal, and at the same time will fuse or melt

the end of the electrode. This molten portion of the electrode will fuse into the puddle of the parent metal, producing a weld.

b. Th carbon arc method of welding is to produce an arc between the parent metal and a carbon electrode. *Figure 40.* The arc thus produced will melt the parent metal, and the operator may now add metal to this molten puddle by means of a filler rod.

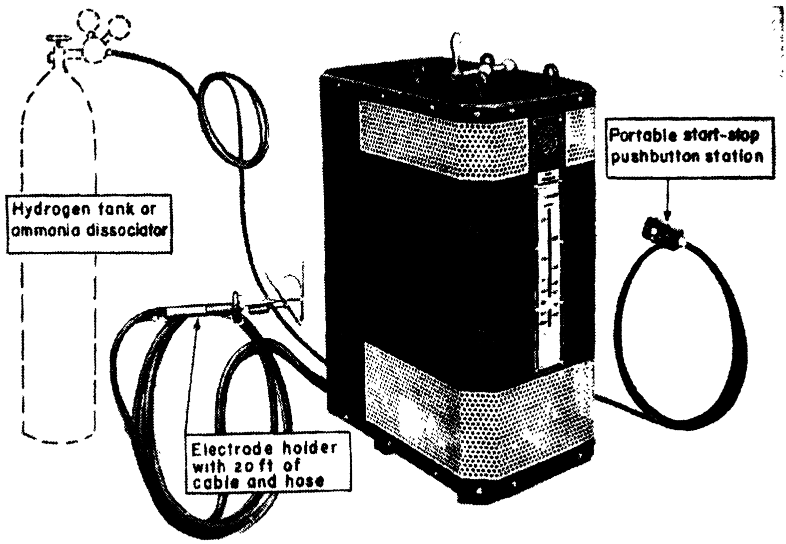


Figure 41. Atomic—Hydrogen welding apparatus
(Courtesy of: General Electric Company)

c. The atomic-hydrogen method of welding is somewhat the same as the metallic electrode method, with the additional procedure of injecting hydrogen around the electric arc. Usually A. C. current is used, which instead of passing through the metal being welded, passes from one tungsten electrode to another. The temperature produced, approximately 7500° C., is the result of the hydrogen becoming atomic hydrogen as it passes through the arc, and then being converted back to molecular hydrogen, thus releasing considerable heat as it hits the metal to be welded. The hydrogen also prevents oxidation. *Figure 41.*

d. Electric arc cutting is usually done by using the carbon electrode. The operator strikes an arc between the carbon electrode and the work to be cut; the arc produced melts the metal. The work is put in such a position that the molten metal will drop away.

51. Principles of Electric Resistance Welding

Resistance welding is done by passing a heavy current through the metal to be welded until the metal becomes hot enough to melt at the spot desired; whatever parts are to be fused then put together; after the current has been discontinued, fusion takes place.

a. Spot welding is usually accomplished on thin pieces of steel; it consists of lapping two pieces of metal and then clamping the

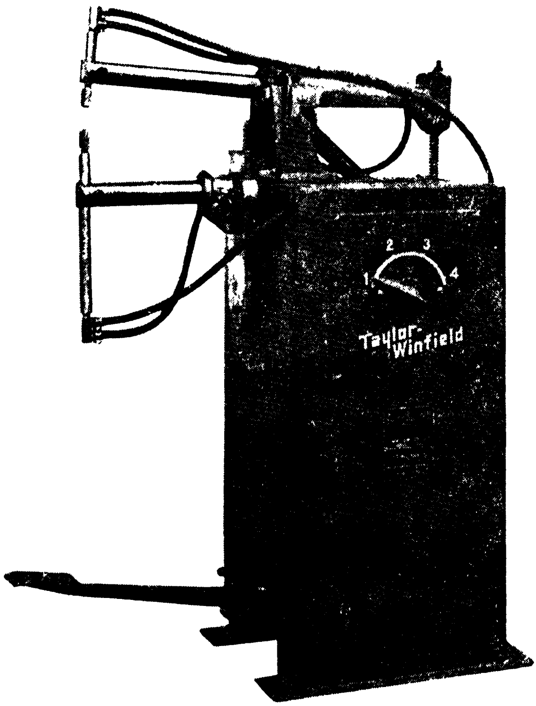


Figure 42. Typical spot welding machine: The electrodes are water cooled, the transformer is adjustable to four different heats and operating switch is located below the transformer and is operated by the vertical rod
(Courtesy of: The Taylor-Winfield Corporation)

joint between two electrodes. A current is then passed between the two electrodes; the resistance of the steel heats the metal at the clamped spot, and the clamping action results in a fusion of the metal at that particular spot. *Figure 42.* This method is becoming very popular in manufacturing processes, either as a preliminary step to other forms of welding or as a final procedure. Many automatic machines have been developed using this method of welding. Automobile bodies are the best example of how the electric spot welding methods have improved during the last decade.

b. Butt welding consists of clamping the two metals to be welded together in separate electrode jaws. The two metals are then brought together and touched. *Figure 43.* The heavy current pass-

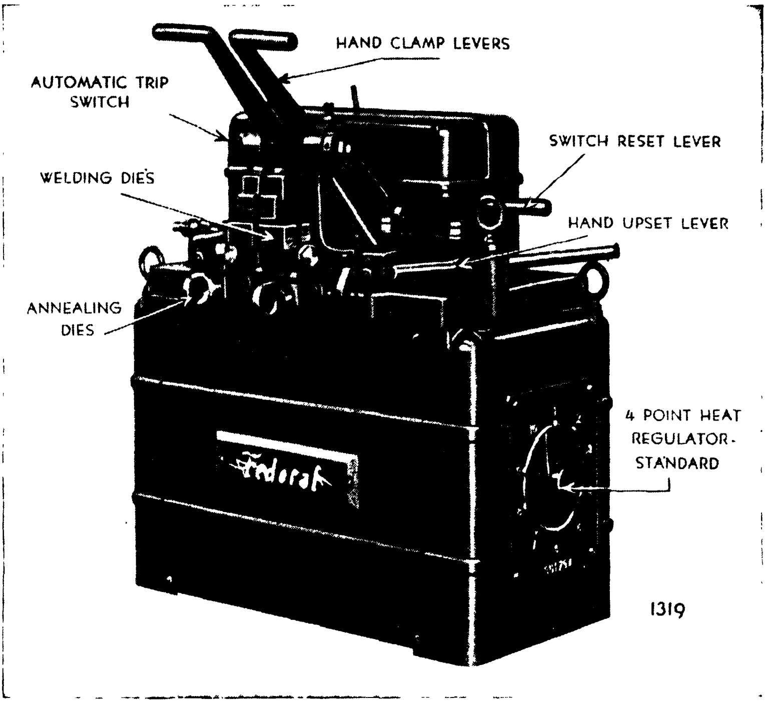


Figure 43. Butt welding machine
(Courtesy of: The Federal Machine and Welder Company)

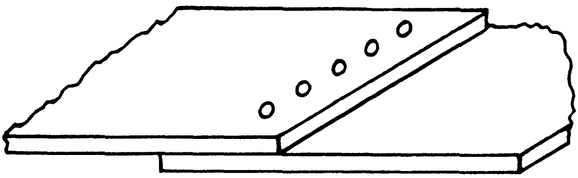


Figure 44. Metal prepared for projection welding: A. P.ojections in one sheet of metal

ing between them will heat the edges to the fusion point, by slightly pressing the two pieces together, the metals will fuse together and became one piece. Flash welding is a form of butt welding which

uses considerable pressure to join the parts together, but does not allow the metals to reach the molten state. This, also, is a very popular method of welding and is used extensively in production work.

c. Projection welding consists of welding two sheets of steel together by pressing raised portions on one piece into contact with the other. As these raised portions touch the other sheet of steel, the current flow at the point melts and fuses the two pieces together. The advantage of this method is to locate the welds at certain advantageous points. *Figure 44.*

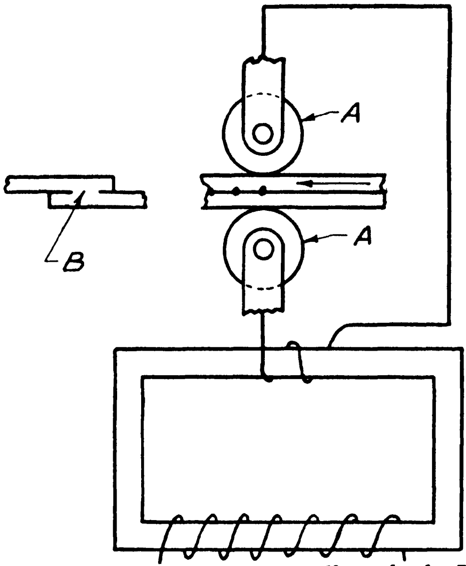


Figure 45. Seam welding circuit: A. Copper alloy wheels, B. The weld proper

d. Seam welding produces a continuous, or non-intermittent, seam weld near the edge of two metals by using two rollers. As these rollers travel over the metal, the current passing between them heats the two pieces of metal to the fusion point. This might be called a seam, spot-weld method. *Figure 45.*

52. Fundamental Arc Welding Practice

All arc welding, metallic arc, carbon arc, direct current, alternating current, or atomic-hydrogen, are fundamentally the same. In practice, the metallic direct current machine is the most used. The limits of application are very few, as practically any metal can be arc welded. Successful arc welds of stainless steel, copper, brass, aluminum, etc., are an everyday occurrence. Problems of preparing the metal for welding by chamfering and preheating are sim-

ilar for arc welding, as for all other welding. The finished weld must be heat-treated to bring out the full properties of the completed seam, although mechanical working of the seam improves the properties considerably. When welding odd-shaped articles where "magnetic blow" offers some difficulty, alternating-current arc-welding is invariably used. *Figure 46.* Production welding usually uses coated electrodes. Carbon arc welding has a very popular application in copper welding ("long arc process"). Atomic-

Figure 46. A.C. transformer arc welder
(Courtesy of: Westinghouse Electric and Mfg. Company)

hydrogen welding is popular where the very best results are adamant, and the properties of the finished weld must be extremely high.

53. Fundamental Resistance Welding Practice

All resistance welding requires enough current to heat the metal

being welded to its plastic, or molten, state (usually the plastic state). The welds are done very rapidly and the resultant weld is very clean and strong. The electrodes must contain a high-conductivity metal and also a wear-resisting metal, usually copper and tungsten respectively. The proper application of resistance depends upon the correct values of the following variables: (1) Time, (2) Current, (3) Pressure, and (4) Area of contact between the electrode and the metal being welded. As the metal being welded must be carefully cleaned, the operator should protect himself from the harmful rays and the flying sparks. Some of the automatic machines have a casing surrounding the weld, with windows inserted to enable the operator to observe the weld while being protected.

54. Safety in Electric Welding

Following are some safety rules that must be religiously observed if accidents are to be prevented:

(1) The eyes must be protected from harmful rays and sparks.

(2) Recommended clothing and shoes must always be worn when using one of these machines.

(3) Open pockets and cuffs must not be worn, for they may catch hot sparks and the clothing may be ignited.

(4) The floor on which the operator stands should be kept as dry as possible to eliminate the chance of an electrical shock.

(5) Only an experienced electrician should work on the electrical power connection used in the machine.

(6) The operator should wear heavy, gauntlet-type gloves.

(7) When arc-welding, all skin should be covered to prevent severe skin burns from the arc rays.

(8) The operator should provide adequate ventilation to protect the respiratory organs from harmful irritating fumes that sometimes emanate from an electric weld.

55. Review Questions

1. What produces the heat in electric welding?
2. What kind of electrode is used in carbon arc-welding?
3. What is meant by the arc core?
4. What kind of current is most popular for arc welding?
5. What kind of current is produced by a transformer?
6. What type of electric welding was developed by Thompson?
7. The development of electric welding was dependent upon the growth of what great industry?

8. Name four different types of electric welding.
9. Why is electric resistance-welding more popular than electric arc-welding?
10. When and by whom was the fluxed electrode invented?
11. Who introduced electric arc welding into the United States?
12. Why does atomic-hydrogen-welding produce better welds?
13. What is projection welding?
14. What is used as the filler metal when one uses the metallic arc method?
15. Why is a certain form of spot welding called gun welding?
16. May metal be cut by the electric arc?
17. When was the electric dynamo invented?
18. What was the first application of arc welding?
19. Why was arc welding first considered impracticable?
20. What are the two fundamental types of electric welding?

CHAPTER IV

ELECTRIC DIRECT CURRENT ARC WELDING PRACTICE, EQUIPMENT AND SUPPLIES

The following paragraphs explain the construction, maintenance, the use of various kinds of direct-current, electric-arc-welding apparatus. Enough specifications are given to enable the reader to understand the limits of use, and the various uses for which the equipment and supplies of the manufacturers are especially adapted.

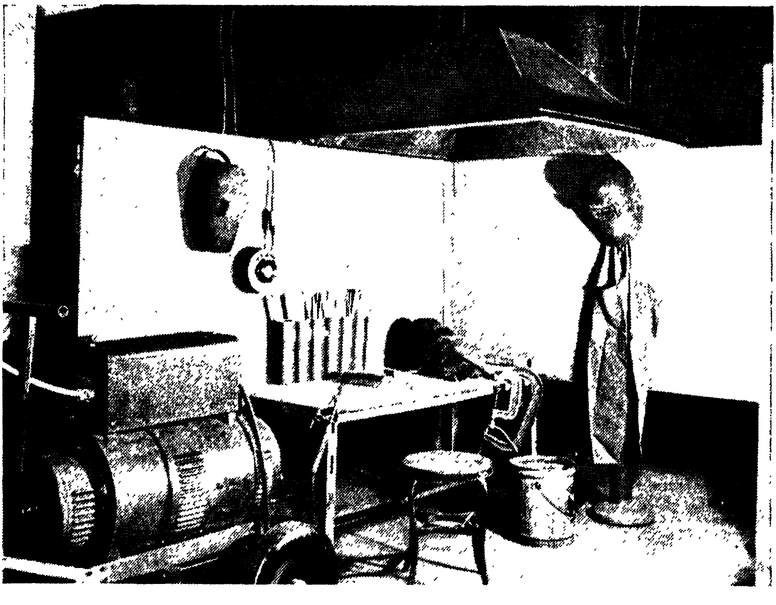


Figure 47. A complete D.C. arc welding station: Notice the metal screens, the table, the electrode receptacles, the C clamps, the protective clothing, etc.
(Courtesy of: Hobart Bros. Company)

56. The Arc Welding Station

The essential parts which are included in any direct-current, arc-welding station are: (1) A.C. motor or gasoline engine, (2) a D.C. generator, (3) an electrode holder, (4) two superflexible, large-sized, rubber-coated cables. *Figure 47.*

57. The Direct-Current, Arc-Welding Generator

The task of the generator is extremely difficult, for as the operator strikes the arc, the voltage drops instantaneously and the current flow goes to a maximum. The generator is necessarily of special design, and incorporates features not found in any other electric generator.

The generator is used to produce direct current. It must produce enough current at a constant rate to furnish heat to melt whatever thickness of metal is to be welded. The apparatus must be safe to use so that no chance of injury is likely to befall the operator. It must be of sturdy construction and must stand many years of use. It must furnish electricity for welding at a constant rating up to its rated capacity, regardless of how heavy the demand, or how irregular the condition.

The generator is equipped with one or two regulating mediums. If one medium is used, this adjustment regulates both the amperage and the voltage of the unit. If two adjustments are used, one is usually for the amperage and one for the voltage.

To understand these adjustments and to realize what the various readings mean, it must be remembered that the *amperage* denotes the quantity of electricity; upon it depends the amount of head being produced at the weld; whereas, the *voltage* denotes the pres-

Metal Thickness	Electrode Size Dia	Current Value Amperes	Approx. Voltage	Speed of Welding Minutes Per Foot	Amount of Metal Deposited Per Hour in Pounds
1/32*	1/32	20	15	....	...
1/16*	1/16	35	15	....	1.5
1/8	1/8	90	17	2.3	3
3/16	5/32	120	19	3.5	3.5
1/4	5/32	145	20	5	3.5
3/8	3/16	155	21	8.5	4
1/2	3/16	170	22	12	4
3/4	1/4	195	22	15	5
1	1/4	215	22	17.5	5

* Coated electrode only—1/32 is No. 22 gauge, 1/16 is No. 16 gauge.

Figure 48. A Table of arc welding values for welding, Bare electrode flat butt welds—using coated electrodes increase current values sligntly. For lap or tee welds increase current values slightly. The above values are approximate and must be varied to apply to the particular case

sure of the electricity and upon it depends the ability to strike and hold an arc. The more voltage, the longer the arc. *Figure 48* shows

the various thicknesses of metal to be welded, and also shows the size of electrodes to be used for these different conditions.

When the machine is not being used, even though it is running, no amperage is being produced. The ammeter will read *zero,* except when the machine is being used for producing an arc, or when a current is flowing. The voltmeter will register at all times except when the machine is not running. The voltmeter, therefore, will indicate two types of voltage: (a) open-circuit voltage, (b) closed-circuit voltage. The open-circuit voltage is the reading the meter will have when the machine is running, but not being used to produce an arc. The open-circuit voltage of the generator is adjustable as well as the closed voltage, and it rarely exceeds 60-80 volts. Because of this low voltage there is no danger of serious shock from the machine. The closed-circuit voltage value may be seen from *Figure 48.* It is much lower than the open voltage, meaning that when the machine starts to produce an arc, the pressure which forces the amperes through the air gap now decreases; the amount of this closed-circuit voltage is very important. If the closed-circuit voltage is too high, the welding will be very brittle and will have many pits and air holes in it. Whereas, if it is too low, it will be almost impossible to strike and maintain an arc.

The generator produces electric energy (watts) which, for the benefit of understanding, is divided into voltage and amperage both of which are indicated on dials mounted on the machine. These meters (gauges) give the relative values of these two. The generator is especially constructed to produce a high amperage at a low voltage. Machines of 40 to 100, 40 to 200, 40 to 300, and up capacity are available. The generator must be specially built to furnish this current. The current produced by the generator should be very steady, and the voltage must not fluctuate during the welding procedure. A steady current is maintained by special devices incorporated in the design of the generator. Compensation poles are built into the generator so that these coils over-lap the main field coils, producing a stable arc. A reactor is also used. This is an electrical device which acts as a current shock absorber; it absorbs the current fluctuations and smooths out the flow of current to the arc. It consists essentially of a huge coil of wire, wound on a laminated metal core and connected in series with the arc. *Figures 49, 50 and 51.*

Some machines use a separate exciter to maintain good voltage and amperage characteristics. The exciter is a small generator, electrically connected to the field windings of the large generator.

This exciter keeps a constant voltage on the main fields and also prevents them from reversing this polarity. The electric arc length naturally varies slightly, depending upon the steadiness of the operator; when this changes, the voltage and the amperage tend to fluctuate. Most of the machines on the market at the present time are able to produce remarkably consistent arcs under varied conditions because of the improved designs they have incorporated in their machines. *Figure 51.* The generator may be a separate

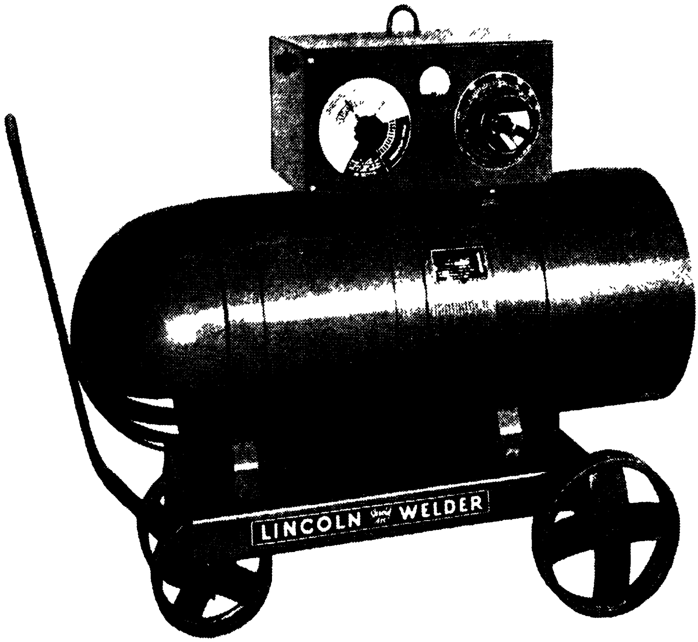


Figure 49. A horizontal generator with electric drive: Note the wheels for portability
(Courtesy of: The Lincoln Electric Company)

part, or it may be built into the same housing as the motor. Also, some models are built into a vertical position as well as a horizontal position. If a separate housing is used to house the generator and motor, a flexible coupling is used to connect the two. The generator bearings are usually ball and roller bearings. The cylindrical type of commutator brushes are used. These brushes must make good contact with the commutator, and the commutator itself must be in excellent condition to produce satisfactory arc welding. (See Chapter 18 for service information on arc-welding

equipment.) The apparatus should be kept clean and away from any corrosive elements.

58. Typical D.C. Arc-Welding Equipment

As mentioned before the generator may be driven by a belt, a gasoline engine, or an electric motor. The gasoline engine is used in remote localities, or on construction work where electricity is not available. Wherever possible the electric-motor drive is used. Its construction, housing, bearings, etc., are similar to the generator. Electrically, it is usually an induction motor using 60 cycle, 3 phase current of either 220 or 440 volts. The motor is always equipped with a manual switch, a magnetic starter, and an overload, cut-out, safety switch. The motor size varies with the generator size. A 10 to 15 H.P. motor is usually used to drive a 200 amp. 20 V. to 40 V. generator.

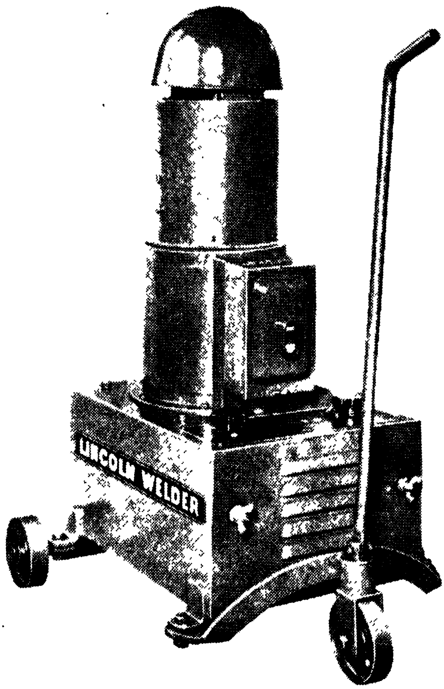


Figure 50. A vertical generator
(Courtesy of: The Lincoln Electric Company)

The electric motor or the gasoline engine used is of typical construction and will not be discussed in any detail in this book. A hand switch is also provided to shut the machine off, while two heavy, super-flexible, rubber-covered cables carry the electricity to

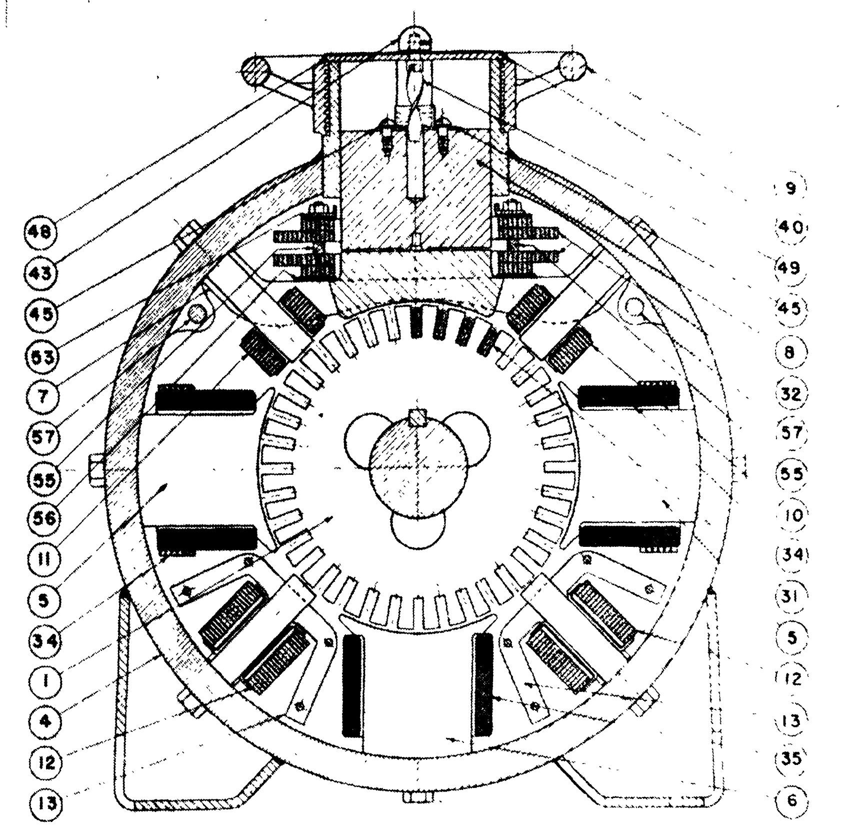


Figure 51. A variable magnetic gap D.C. arc welder: *1* Rotor; *2* Housing; *5* Field pole; *8* Movable field pole; *9* Hand wheel
(Courtesy of: Air Reduction Sales Company)

the work and return it to the generator. One is the positive cable and the other the negative. The positive (Anode) is usually clamped to the work to be welded; while the negative cable (Cathode), or electrode cable, runs to the electrode holder. The electrode holder is a clamping device, provided with an insulated handle, which is used to hold the metallic or carbon electrodes. *Figure 52.* The

cables are superflexible, to minimize the strain on the operator while the work is in progress.

59. Automatic Direct-Current Welding Machines

Direct-current, arc-welding machines are adaptable to automatic welding. In these machines the electrode wire is rolled up on a drum and is fed to the work at a certain rate. At the same time the work travels along and the seam is automatically laid by the welder.

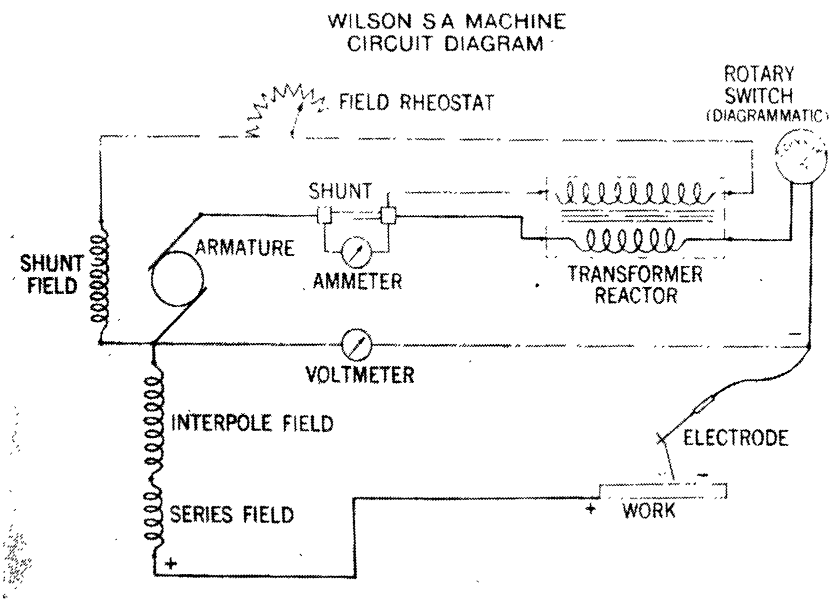


Figure 52. A D.C. arc welding circuit wiring diagram: Wilson SA
(Courtesy of: Air Reduction Sales Company)

The speed of the welding operator and the speed of the electrode feed are regulated so that a perfect weld is produced. *Figure 53.* Such machines find wide use in industries which produce many parts to identical specifications.

60. Storage Battery Welders

The storage batteries are sometimes used as a source of welding current, either for arc or resistance welding. Batteries were the first source of power for arc welding. Edison cells, or lead-acid cells, may be connected in a combination of series and parallel to produce very high amperages at safe voltages. The size and weight

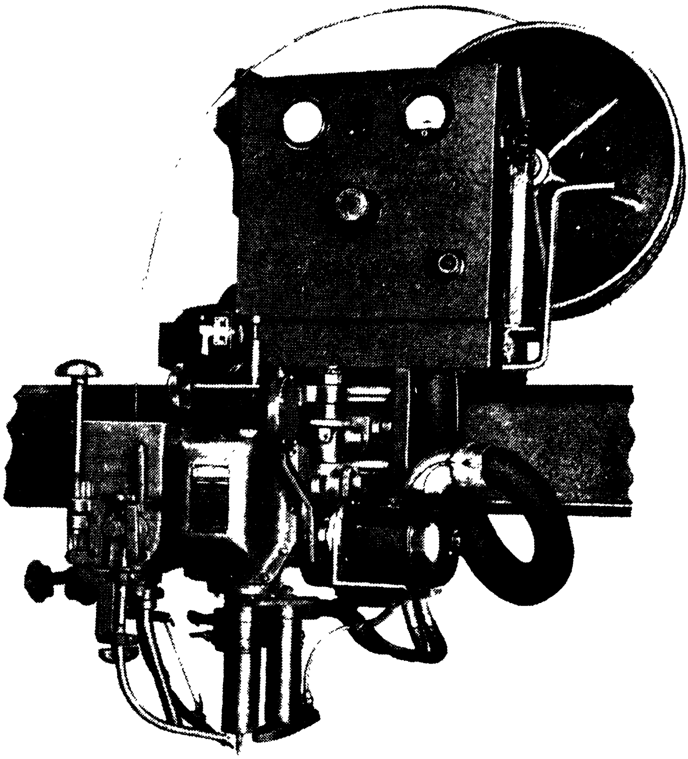


Figure 53. An Automatic D.C. arc welding machine: May use carbon electric flux feeder, and filler rod feeder (large drum upper right) or may use automatic electric feeder. It is used together with a D.C. arc welding machine
(Courtesy of: The Lincoln Electric Company)

of the complete apparatus keeps it from being very popular, and the matter of maintaining and of recharging the batteries periodically is another drawback to the extensive use of this method of

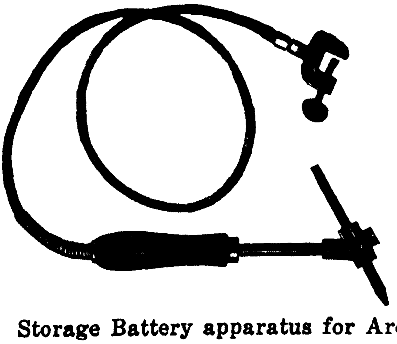


Figure 54. Storage Battery apparatus for Arc Welding
(Courtesy of: Electric Storage Battery Company)

electric welding. It is quite frequently used in automobile shops to carbon-arc-weld storage battery parts together. *Figure 54.*

61. Vacuum Tube Welders

Another type of welder that has the advantage of few, if any, moving parts is used somewhat, but is not so popular as the motor-generator type. This uses the principle of the rectifier tube found in storage battery chargers and Alternating Current radio receiv-

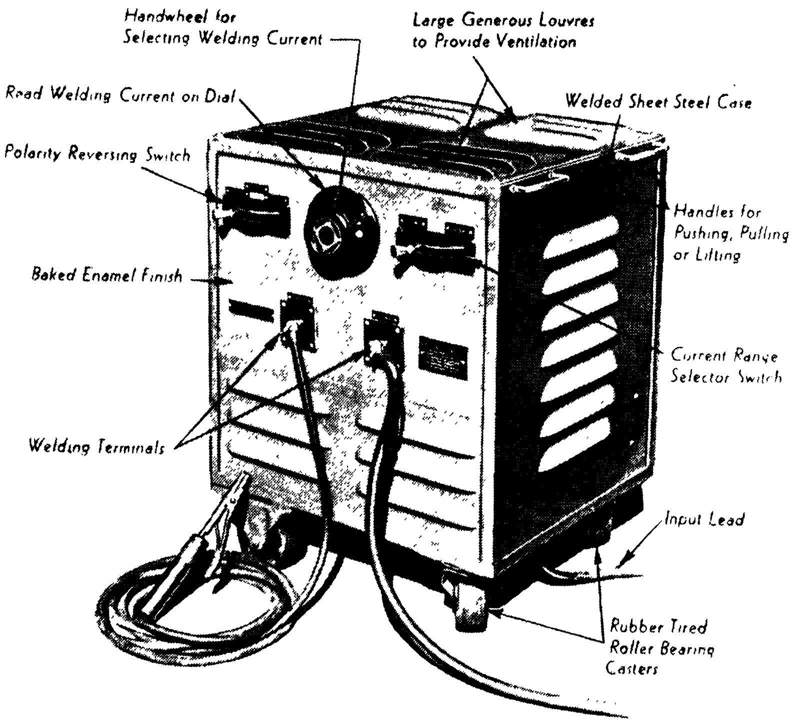


Figure 55. A rectifier tube arc welding apparatus
(Courtesy of: Allis-Chalmers Mfg. Company)

ers. The principle of operation is to pass the current through a gaseous gap from a sharp electrode to a flat-faced electrode. The current goes through the gas in this direction easily, but has great difficulty in traversing from the flat face (carbon) to the tungsten wire point. In this manner one-half the wave of the A.C. current is permitted to go on, but the other one-half wave is stopped almost completely. By using two bulbs both sides of the A.C. current can

be rectified into D.C. The size of the bulbs or the number of bulbs determines the amount of current. This type of welding apparatus is not as frequently used at the present time as the motor-generator sets. *Figure 55.*

62. Cables

Large diameter, superflexible cables are used to carry the current from the generator to the work and from the electrode back to the

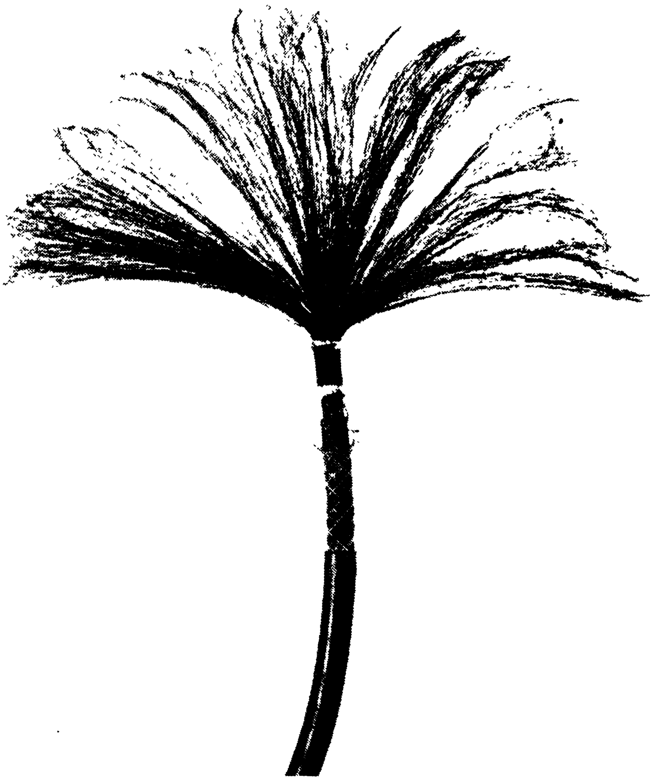


Figure 56. Arc welding cable
(Courtesy of: The Lincoln Electric Company)

machine. These cables are well insulated with a durable, waterproof, fabric-reinforced cable. This cable usually lies on the floor and is subjected to considerable wear. The voltage carried by the cables is not excessive, varying between 14 volts and approximately 80 volts. This would lead us to believe that insulation similar to house wiring insulation would be sufficient, but because of the use

of the cable, it must be insulated with rubber-fabric strand and with a heavy rubber coating on the exterior. The cable is produced in several sizes, the following being the popular numbers: 4, 2, 1, 0, 00, 000, and 0000. The smaller the number, the larger the size of the cable. The above cable numbers have respective diameters of .531″, .640″, .694″, .827″, and .959″. It will be noted that the diameter of these cables is rather large and yet the cable must be very flexible in order to reduce the strain on the arc welder's hand as he welds, and also to permit easy installation of the cable. *Figure 56.* To produce this flexibility, as many as 800 to 2500 wires are used in each cable. These wires are stranded and built into a very strong, flexible cable. *Figure 56.*

The ground cable used for electric arc-welding does not necessarily have to be as flexible as the one attached to the electrode holder; some people use a less expensive cable for this purpose using fewer strands. Some welders use the metal framework of the building instead of a ground cable. However, the common practice is to use identical cables, both for the ground and the electrode cable. Some common sizes of ground cables are numbers 2, 1, 0, 00, 000, and 0000. The length of the cable has considerable effect on the size to be used for certain capacity machines.

Cable No.	Cable Dia.	Current Capacity		
		0-50 Ft.	50-100 Ft.	100-250 Ft.
0000 4/0	.959	1000	600	. . .*
000 3/0	.827	800	400	. . .*
00 2/0	.754	600	300	200
0 0	.694	300	250	175
1	.644	250	200	150
2	.604	200	150	100
4	.531	100	. . .†	. . .†

* This distance not recommended for high amperages.
† These distances not used for the No. 4 cable.

Figure 57. Arc welding cable specifications
(Courtesy of: The Lincoln Electric Company)

The wiring to the motor, in case a motor-driven generator is used, will usually come under the supervision of a qualified electrician. A table of recommended wire sizes is shown in *Figure 57.* The values referred to are to be applied to cable lengths not exceeding 100 feet.

The cables are fastened to the various connections by means of lugs which are made of copper and are soldered to the cables. The lugs provide a firm means of attaching the cables to the generator terminals and to the ground connection.

63. Electrode Holders

The electrode holder is the part held by the welder and is used to hold the metallic or carbon electrodes. Many different styles and models have been produced, but they all have some of the following characteristics: The cable is fastened either to the electrode holder inside of the handle or to a clamping mechanism. The most common arrangement is to attach the cable inside of the handle. The handle is made of an electrical, insulating material which also has a high heat-resistance quality. These holders are built to produce a balanced feeling when held in the operator's hand, with the cable draped over the operator's arm, and with the average length of the metallic electrode in the holder. *Figure 58.*

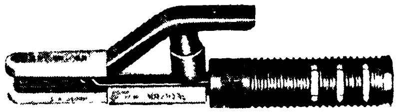


Figure 58. Electrode holder: It is completely insulated, the jaws are special alloy copper and the cable may be either soldered or clamped to it. Ventilated for cooling
(Courtesy of: Jackson Products)

Two means are used to clamp the electrode in the holder. This is usually done by means of a clamp construction with a coil spring to produce the necessary good contact between the holder and the electrode. The other method is to use a cantilever spring. This consists of two pieces of some spring-like metal extending from the electrode handle and equipped with notches. The operator simply has to slide the electrode between the two pieces of metal and the electrode is firmly clamped in place. It is, therefore, advisable to clean the electrode at the points where it is to be connected. This may be done by means of a wire brush. The electrode clamps themselves should also be kept clean. Use a file, sandpaper, or any other means to do this. When shielded or coated electrodes are used, it is imperative that coated material be scraped off the electrode at the point of contact with the electrode holder.

When welding heavy work, these electrode holders are sometimes equipped with shields, i.e., a small asbestos heat-resisting plate, preventing the radiation of heat from the work directly into the operator's hand. Another way of increasing the operator's

comfort is to water-cool the handle of the electrode holder. This is done by circulating water in and out of the handle by means of flexible rubber hose. These water-cooled holders are especially popular in carbon arc-welding. *Figure 59.*

64. Shields (Helmets)

Electric arc-welding necessitates the use of some special protective device for both the face and the eyes. This device may either be mounted and supported on the head, or may be held in one's hand; the former one is called the head shield or helmet, and the latter usually called a hand shield. *Figure 60.* This device is made of black fiber formed in a shape which covers the front half of the

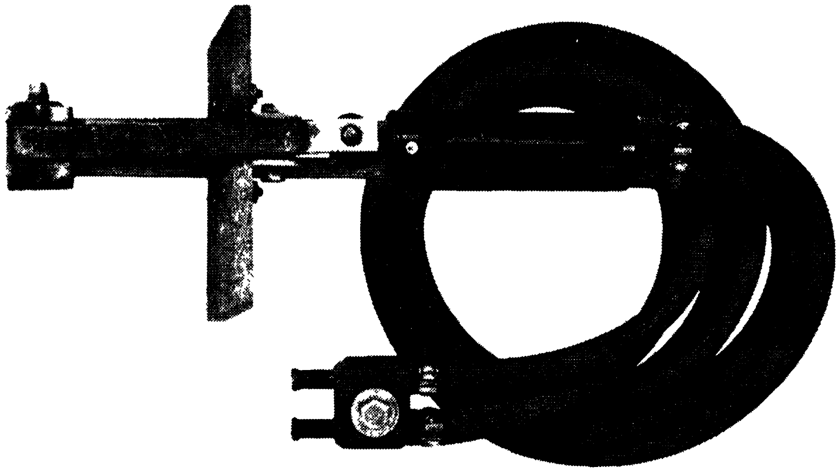


Figure 59. A water cooled electrode holder (carbon arc)
(Courtesy of: The Lincoln Electric Company)

head. An aperture at the level of the eyes provides visibility. This aperture is approximately 4¼″ x 2″, and is provided with two glass lenses. The outer lens, which is of double strength glass, is used to protect the inner and more expensive lens from sparks and abuse. The inner lens, which is especially prepared glass of No. 10, No. 11, or No. 12 visibility, is used to eliminate practically all of the infra-red and ultra-violet rays produced by the electric arc. This inner lens transmits only the red, green, and yellow rays produced by the arc. As filter lenses are quite expensive, they should be very carefully handled to prevent breakage. The filter lenses are of such density that one cannot see any object through them until the arc is struck.

The helmet, or head shield, has a swing mounting whereby the forward part of the helmet may be lifted above the welder's face, without removing the helmet from the head. Spring clips usually provide a means for a snug mounting of this helmet on the head. Some arc welders, who work continuously for 8 or 9 hours, find that a pair of ordinary welding goggles underneath the welding helmet makes the welding more comfortable, and reduces eye strain (the goggles especially eliminate the reflect glare around the back

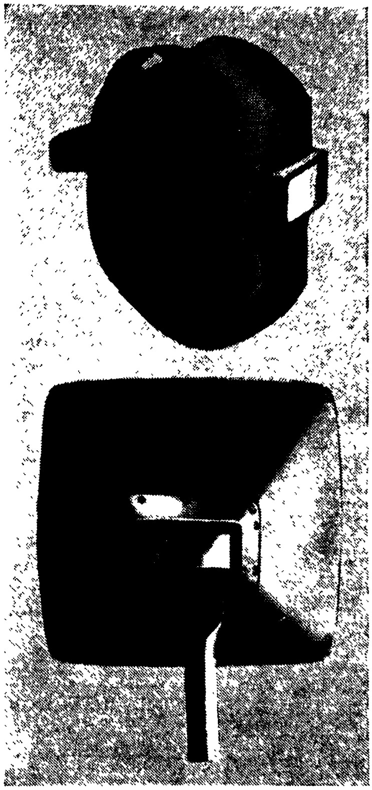


Figure 60. A helmet and a hand shield
(Courtesy of: The Lincoln Electric Company)

of the helmet). Some helmets are available into which fresh air is fed by means of a hose in order to increase the comfort of the operator.

A good grade of arc welding lens will remove approximately 99.5% of the infra-red rays and 99.75% of the ultra-violet rays. These figures have been developed by the U. S. Bureau of Standards, which also reports that many of the lenses remove 100% of these rays. Number 10 is the common shade number used for welding

with metallic electrodes, and number 12 for carbon arc welding. However, other shade numbers may be obtained and used. The higher shade numbers provide for practically no transmission of infra-red or ultra-violet rays. Ultra-violet rays in excess will cause pain 8 to 18 hours after the exposure, and will result in pains in the back of the eyeball. The effect is said to be chemical. Infra-red

Figure 61. Adequate arc welding clothing: Sleeves, gloves, and flash goggles
(Courtesy of: General Electric Company)

light rays tend to injure the sight and every precaution should be taken to shield the eyes from them.

Some cover (outer lens) glass is especially treated and resists the adhesion of metallic particles to its surface. The glass may be used considerably longer than the old style lens. All that is needed to remove these particles from the glass surface is to wipe them off with a soft cloth.

65. Special Arc Welding Clothing

While an arc weld is in process, the molten flux and the metal itself sometimes spatter for a considerable distance around the article being welded. The operator must, therefore, protect himself carefully from the danger of being burned by these hot particles. Such clothing as gloves, gauntlet sleeves, aprons, and leggings are sometimes necessary, depending upon the type of welding being performed. *Figure 61.* It is recommended that all of these articles be made of leather (usually chrome leather) with the exception of the leggings and gloves, which are sometimes made of a combination of cloth and asbestos. It is further recommended that the operator use high-top shoes, meaning shoes that go over the ankle rather than the more common type of oxford. Trousers worn by the welder should not have cuffs, for they may catch the burning particles as they fall.

Another recommendation is that all the clothing worn be carefully inspected to eliminate any place where the metal may catch and burn, such as the open pockets and cuffs in the trousers, etc. It would seem on first thought that clothing of this kind would be extremely uncomfortable, because of the heat, but the protection provided is more important, and furthermore the discomfort is not so great as might be expected.

The clothing, other than the garments mentioned, should be of a heavy material because of the fact that thin clothing will permit the infra-red and ultra-violet rays to penetrate to the skin. If the skin is not properly covered, after one or two hours' work without protection, the operator will become severely "sunburned," resulting in painful burns. Such burns, if they do occur, should be treated in a manner similar to a severe sunburn; and if very severe, a physician should be consulted.

66. Metallic Electrodes

As mentioned previously, metallic electrodes come in four types:

1. **Bare electrodes**
2. **Dusted electrodes**
3. Flux-dipped
4. Woven flux electrodes

Most of these electrodes are physically very similar in their specifications with the exception of the flux used. *Figure 62.* The common sizes of the bare electrodes are as follows: $1/8''$, $5/32''$, $3/16''$, $7/32''$, $1/4''$, $5/16''$, and $3/8''$ diameter. These rods come in lengths of 14″ for all sizes and may also be obtained in 18″ lengths for the $3/8''$ sizes. When ordering, it should be remembered that the electrodes are packed in fifty-pound packages, and that if orders are

given for quantities other than multiples of 50 lbs., the cost will be greater. The most common electrodes are made of mild steel, but almost any metal alloy may be purchased.

The arc-welding electrode will always produce a small amount of spatter. The metal in the finished weld should have a density of approximately 7.85 grams per cubic centimeter.

The bare electrode should have the following chemical composition:

Carbon	.13-.18%
Manganese	.14-.60%
Phosphorus and sulphur.....	.04%-maximum
Silicon	.08%-maximum

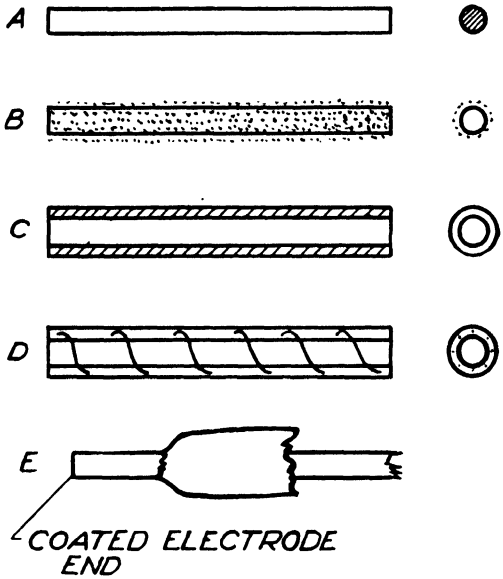


Figure 62. Various types of electrodes, A. Bare, B. Dusted, C. Coated, D. Coated with thread or wire re-enforcements, E. End of electrode that is put in electrode holder

The bare electrode, with few exceptions, can only be used for mild steel welding, as it is usually difficult to produce satisfactory welding with a bare electrode. However, because of their low cost, and since a competent welder can produce very satisfactory welds with them, these electrodes are used to quite an extent. A slightly more expensive electrode is dust-coated with a flux to help reduce the oxidizing action of the arc. For such welding practice as the high-temperature steel, tool steels, molybdenum steels, and for especially strong, mild-steel welds, flux coating and flux woven electrodes are

used. Special electrodes have been developed for each kind of material and type of weld. *Figure 63.*

Electrodes are usually coated by dipping the~~m in~~ a liquid flux solution to produce a coating of sufficient thickness. The coating during the arc process changes to a neutral, or reducing, gas carbon monoxide, or hydrogen (CO or H_2), which, as it surrounds the arc proper, prevents the air from coming in contact with the molten metal, and removes any oxygen which may approach the molten metal by combining with it. However, it usually does not protect the very hot metal after the arc leaves that point. The flux coated

Figure 63. The proper way to store electrodes to eliminate confusion
(Courtesy of: Hobart Bros. Company)

electrodes (some have thread or wire reinforcements to keep the flux from cracking) require a flux which, in addition to providing a neutral gas field for the arc, also contain special ingredients which promote fusion and tend to remove impurities from the molten metal by forming a slag. The flux forming the protective covering commonly consists of asbestos, felspar, mica, steatite, titanium dioxide, calcium carbonate, magnesium carbonate and various aluminas. These neutral gas-producers are: carbon hydrates, such as paper, cotton, wood flour, cellulose, starch, and dextrin. Some of the special electrodes have metallic salts included in the coating to produce the correct alloy metal in the weld. In addition to the ac-

tion of the flux in the arc proper, the residue forms a coating of material over the weld after solidification, which prevents the air from contacting the still hot metal. A good, flux-coated electrode produces a weld that is similar in appearance to the oxy-acetylene weld, and which has similar properties.

67. Carbon Electrodes

Carbon electrodes are used for carbon arc welding and carbon arc cutting. These electrodes come in sizes ranging from 1/16″ diameter up to 1″ diameter. Rods may be obtained in 12″, and 18″, and 24″ lengths. The quality of the rod must be extremely high, as the structure of the carbon must be uniform. The two qualities of electrodes obtainable are the carbon electrode and the graphite

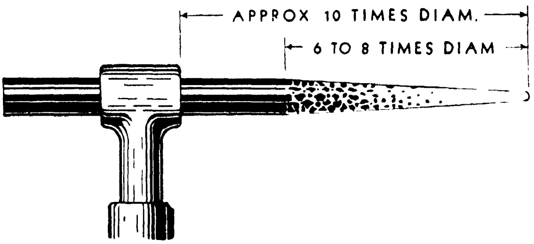


Figure 64. A carbon electrode
(Courtesy of: National Carbon Company, Inc.)

electrode. The graphite has better conductivity and is usually of more nearly uniform quality. The rod should be inserted in the holder with the end, or the point, of the carbon approximately 10 times the diameter of the rod away from the electrode holder. Example, a 1/2″ rod will have its end not over 5″ away from the holder. As the rod is being used, it tends to burn back to the holder. The rod should therefore always be kept pointed, the taper of the point to be approximately 6 to 8 times the diameter of the electrode. *Figure 64.* The various currents required for the different sizes of electrodes are shown in *Figure 65.*

68. Cleaning Equipment

It is very important that metals to be welded be clean. It is impossible to weld over very dirty or corroded surfaces. Many types of equipment and tools have been developed for the purpose. Sandblasting machinery, chipping chisels, hammers, and wire brushes are a few of the popular methods. The amount and size of the welding done usually determines the kind of cleaning apparatus desired. If possible, the first two of the above methods are to be preferred.

69. Electric Arc Characteristics

A study of the properties of the metallic-electrode arc itself reveals some fundamental principles, which should be understood by the welder. The current is understood to be traveling from the metal to the electrode, and the electrons to be traveling from the electrode to the parent metal. Of the total heat produced approximately ⅔ is produced at the parent metal, while ⅓ is liberated at the electrode.

RECOMMENDED CURRENT RANGE FOR HAND WELDING OPERATIONS WITH "INTENSARC" ELECTRODES

Electrode Diameter Inches	Welding Current		Maximum Current Density Amps.Per Sq.In.	Pounds Per Hour Deposited
	Min.	Max.		
⅛	0	35	2890	...
3/16	25	60	2200	...
¼	30	90	1855	...
5/16	80	125	1650	...
⅜	110	165	1510	...
7/16	140	210	1420	1.5
½	170	260	1340	2.5
⅝	230	370	1220	4.5
¾	290	490	1125	6.0
⅞	350	615	1035	...
1	400	750	965	...

Figure 65. Carbon electrode current requirements
(Courtesy of: National Carbon Company, Inc.)

The arc, when viewed through the helmet lens, is seen to be divided into three separate parts: the core, the stream, and the flame. *Figure 66.* The arc flame consists of neutral gases (pale red). These gases come from the electrode and the flux. The arc stream (yellow) is the vaporized metal, while the core (green) is the liquid metal, being transferred to the parent metal, the three electronic activities. If the arc is longer than normal, the flame gases can no longer protect the stream and core, and the metal will form oxides and nitrides, resulting in a very weak and brittle weld. The voltage used, therefore, is very important as to much pressure necessitates a longer arc, resulting in considerable spattering. If the weld progresses too rapidly, the weld will not penetrate; if too slowly, either too much penetration or too much build-up will result.

Sometimes while arc-welding with a D.C. machine, the arc suddenly jumps and runs over to one side without warning. This is

the result of the strong magnetic field built up in the arc and is due to the characteristics of direct current. This trouble is not serious, however, except at the end of a weld.

If the correct voltage, amperage, and arc length are maintained, a good weld must result. The voltage and amperage required for any test may be easily obtained from established tables; however, the correct arc length is entirely the operator's responsibility.

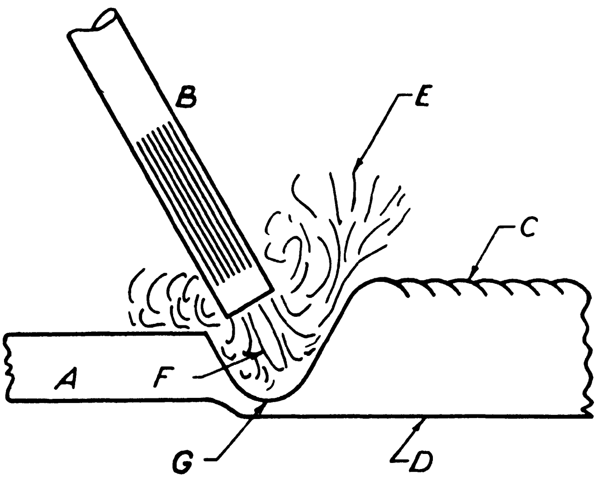


Figure 66. A bare electrode arc weld in the making: A. Base metal, B. Bare electrode, C. Bead, D. Penetration, E. Vaporized metal, dust, and impurities, F. Arc stream, G. Crater

70. Direct Current Welding Practice

Before attempting any special arc welding tasks, it is recommended that the arc welder practice on fundamental welding exercises. The exercises to be performed are the same as acetylene welding. This welding practice should be performed with plain or lightly dusted electrodes, because if coated or fluxed electrodes are used, it is difficult for the beginner to observe the proper technique. Also the fumes are annoying compared with the amount of practice to be gained; and the necessary skills are not fully developed, inasmuch as flux electrode welding is much easier than dusted electrode welding.

Penetration, a clean bead, consistent width of weld, a consistent height of weld, consistent ripples of the bead, and good fusion, are

all just as necessary in arc-welding as they are in gas-welding. The operator should be able to do the following welds:

A. Butt weld
B. Inside Corner weld
C. Outside corner weld
D. Lap weld

All of the above should be done on:

A. A flat surface
B. A vertical surface in a horizontal direction.
C. A vertical surface in a vertical direction.
D. Overhead.

71. Safety in Handling Direct-Current Arc-Welding Equipment

It is very important that the arc welder thoroughly understands the hazards one may encounter in setting up, starting, using, and closing-down an arc welding station. Such things as arc flashes, molten metal in one's shoes or in the clothing, electric shocks, fumes, and burns are to be avoided at all times. The welder should not wear light clothing; the pockets, if any, must be covered and no cuffs should be allowed in the trousers. High shoes only should be worn and safety toes are a necessity. The electric shocks one may receive during welding are not necessarily serious, but they are annoying. By keeping the floor dry, and by using dry gloves one may eliminate this trouble. The arc booth must have well-designed exhaust equipment to remove the fumes as fast as they are formed. Certain special jobs frequently employe forced ventilation to the welder's helmet.

One should never look at an electric arc from any distance less than twenty feet unless the eyes are completely protected by approved lenses. When welding, the face, hands, and body must be completely protected. The ultra-violet and infra-red rays are very harmful. If one should accidentally become "flashed," special treatment should be administered at once, and by a physician, if serious. Eye washes consisting of 2% Butyn, 5% Argyrol are sometimes recommended for such treatment.

72. Assembling the Arc-Welding Equipment

The typical arc welding station consists of:

a. A motor-generator
    (1) Motor 220 V. A.C. three phase 10 H.P.
    (2) Generator 25 volts D.C. 200 ampere capacity.
        1. A manual switch 2. A magnetic switch

b. A ground cable, and an electrode cable, superflexible strand, rubber covered.
c. An electrode holder.
d. A steel bench approximately 30″ high.
e. A stool or chair.
f. A special clamp device or "C" clamps.
g. Spare electrodes.
h. An electrode hanger (insulated).

The booth should be well ventilated and well lighted. All of the cable except the end at the electrode holder should be protected from abuse. The arc welder should be placed close to the booth to keep the arc cables as short as possible and to permit quick and easy adjusting of the machine. Before starting the machine, it is necessary to check all items to be used for arc-welding to see that the equipment is in usable shape.

The Welder:

A. gloves
B. helmet or shield
C. apron
D. shoe cuffs
E. arm cuffs

The Machine:

A. "C" clamps
B. booth curtains
C. fuses of right capacity in the main switch
D. ampere adjustment set to minimum

Supplies:

A. Correct size electrode
B. Clean stock

The rays radiating from an electric arc are much more intense than those from the oxy-acetylene flame. The hands, the face, the arms, and the body must all be protected. Leather gloves with tight fitting cuffs, which fit over the sleeves of the jacket, should be used. The helmet or shield will protect both the face and the eyes from the rays. An apron of heavy material is used to protect the clothing from sparks emitted from the arc. To keep molten metal out of the operator's shoes and also out of the pantleg cuff, a tight fitting tapered cuff is put on the ankle and goes over the shoes. A high shoe is preferred for this work.

The machine should be carefully inspected, cleaned, and oiled before each job is started. A medium grade of automobile oil is used in the plain motor bearings, while ball-bearing units use special

grease. Inspect it to see if the electrode is grounded, and then hang it away from the work to be welded, preferably on a fiber or wood holder. Inspect the commutator after starting the machine; if the brushes are arcing, they should be overhauled before the work proceeds. All arc welding should be performed in a booth, or should be protected from a chance passerby's observation of the arc.

73. Starting the Arc Welder

The experienced welder will observe the following things before starting a machine:

a. Inspect the bearings for oil or grease.

b. Inspect the commutator and brushes for wear.

c. Set the voltage and amperage adjustments to their minimum.

d. Inspect the cables for worn insulation spots.

e. Go over all the electrical connections for tightness.

The steps usually followed to start the welding machine are as follows:

a. See that the electrode holder is not grounded.

b. Close the main switch.

c. Press the magnetic starter "ON" button.

d. Adjust the machine to correct voltage and amperage. *Figure 48.*

e. Check the brushes and commutator for arcing.

f. Insert the correct size electrode in the electrode holder.

74. Shutting Down the Arc Welding Machine

The shutting down of the arc welding station is usually as follows:

a. Hang the empty electrode holder on its insulated hook.

b. Press the "OFF" button on the machine.

c. Pull the manual switch to the "OFF" position.

d. Set the amperage adjustment to the minimum setting.

e. Cover the machine.

f. Clean the station including,

(1) Electrode holder

(2) Bench

(3) Floor

g. Save the electrodes of usable length

It is very important that the equipment be kept clean, since in arc-welding an oxide is formed which, if allowed to accumulate, will collect on the motor and generator and will deteriorate them

rapidly. The machine should also be kept away from moist or corrosive locations. As practically all the manufacturers have special features constructed in their machinery, it is recommended that the instructions accompanying each be carefully read and understood.

75. Striking the Arc

One of the first lessons one must master, when learning to arc-weld, is to be able to produce the arc between the metallic electrode and the metal. To strike the arc, the electrode must first touch the metal, and the end must then be withdrawn to the correct distance.

At first the electrode will tend either to stick (weld itself) to the parent metal, or when the electrode is withdrawn, the movement will be so great that the voltage cannot maintain the arc, and it will break (go out).

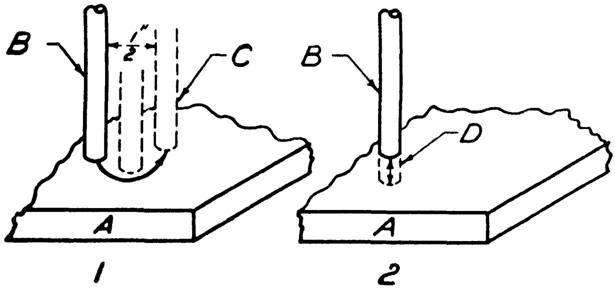


Figure 67. Two methods of striking the arc: *1* A. Base metal, B. Electrode position at the start, C. Electrode position at the end; *2* A. Base metal, B. Electrode at the start, D. Motion of the electrode (this latter method not recommended)

There are two common methods of producing the arc. The welder may use a glancing or scratching motion with the end of the electrode, or he may use a straight down and up motion. *Figure 67.*

76. Positioning for Arc Welding (Running a Bead)

Before an arc welder attempts to weld any seams, or joints, he should become a proficient bead maker. To practice this, secure a piece of metal 1/8″ to 1/4″ thick, 2″ wide and 6″ long. Ground this metal to the table, preferably at the end upon which the practice is to begin. The grounding may be accomplished by tacking the metal to the table, or better, by clamping it to the table with copper coated clamps.

a. Insert the electrode in the electrode holder, clamping the electrode in the middle (for beginners).

b. Assume a comfortable sitting or standing position.

c. Lower the helmet or place the hand shield in front of the face.

d. Grasp the electrode holder easily in one hand and strike the arc. A slight semi-circular motion should be used (a glancing blow). Lower the electrode slightly for each motion until the electrode contacts the parent metal. As soon as the arc is obtained, lower the electrode toward the work until the arc emits a sharp crackling sound of frying steak.

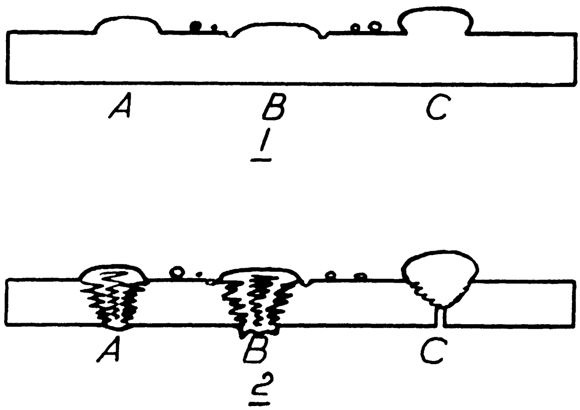


Figure 68. The appearance of bare electrode arc welds: *1* A. A proper bead, B. Too much current or too long an arc, note the splatter and the undersetting at the edge of the bead, C. Insufficient current; *2* A. Correct penetration, B. Too much penetration, C. Insufficient penetration

e. Hold the electrode in a near vertical position (about 20 degrees from vertical).

f. Use no motion for this thickness of metal.

g. Progress either to the right or to the left, gradually lowering the hand as the electrode is used up.

h. Keep looking at the puddle to check its width, and also note the length of the arc.

i. A chalk line put on the metal before the weld is started will help the beginner to maintain a straight line.

k. Upon completing the weld, raise the shield or helmet and inspect the weld for:

1. Alignment	4. Air holes
2. Size of the puddle	5. Spatter
3. Penetration	6. Even bead

Always have an experienced arc welder try the machine before attempting to weld with it, as many hours may be wasted by trying

to learn arc welding with a machine that is out of adjustment. Be sure the machine is set to the correct voltage and amperage for the metal being worked on. *Figure 48.* Having an experienced arc welder observe one's technique when starting, will correct faults which, if they become habits, will be hard to rectify. A good bead on this 1/8″ plate will look very similar to an oxyacetylene weld. It will have a clean, shiny surface, an even bead, good penetration, and good fusion. *Figure 68.*

77. Magnetic Arc Blow

One characteristic of D.C. arc welding, not found when one uses A.C. arc welders, is the fluctuating arc or the arc instability. This action is due to the magnetic field built up around any conductor which carries current. If the electrical flow is constant and always in one direction, this magnetic blow effect is negligible; but if the ground changes position, or if one attempts to weld into a corner or crevice, the fluctuating magnetic field will force the arc to move erratically. The arc might even be broken from the force of this magnetic field. The welder can only take the precaution of grounding the work carefully to minimize this effect, or he may try grounding the work in different positions and places to counteract this condition.

78. Running a Bead on a Flat Surface

Before attempting to weld any type of seam in any position, the arc-welding student should practice laying arc beads on a similar metal. One must be able to make several excellent beads before proceeding to weld the various types of welds. An arc bead is produced by touching the end of the electrode lightly to the metal and withdrawing it to the proper distance (gap). This gap varies with the size and the type of electrode used. Bare electrodes should have a gap of 1/8 to 3/16 of an inch which necessitates a voltage of 20 to 24 volts across the arc. Coated electrodes use a larger gap, 3/16 to 1/4 inch, necessitating 30 to 40 volts across the arc. Perhaps the easiest method a student may use to check on the proper length of an arc is to listen to the sound of the arc. As previously explained, the proper arc gap for bare electrodes has a distinct, crackling or frying sound. Also the metal does not collect on the end of the electrode. Any glutinous collecting on the end of the electrode indicates too long an arc. Coated electrodes also have distinct indications of proper arc length. The sound of the arc is just as indicative, although in this case the arc has a distinct hiss-

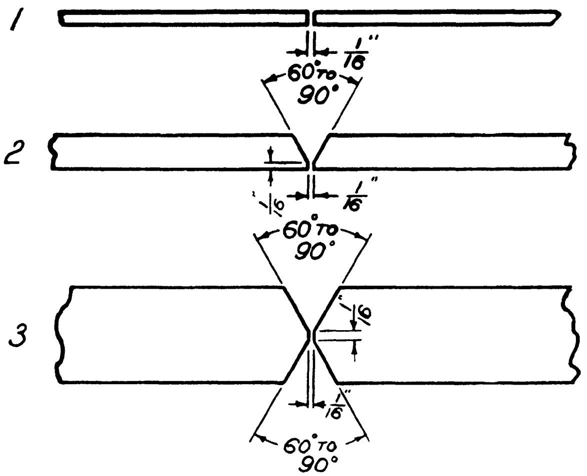


Figure 69. The preparation of steel plates for arc welding: *1* **Thin metal** up to ⅛"; *2* **Metal of ⅛" thickness up that can be welded on one side; *3* Metal** of ¼" thickness and up that may be welded on both sides

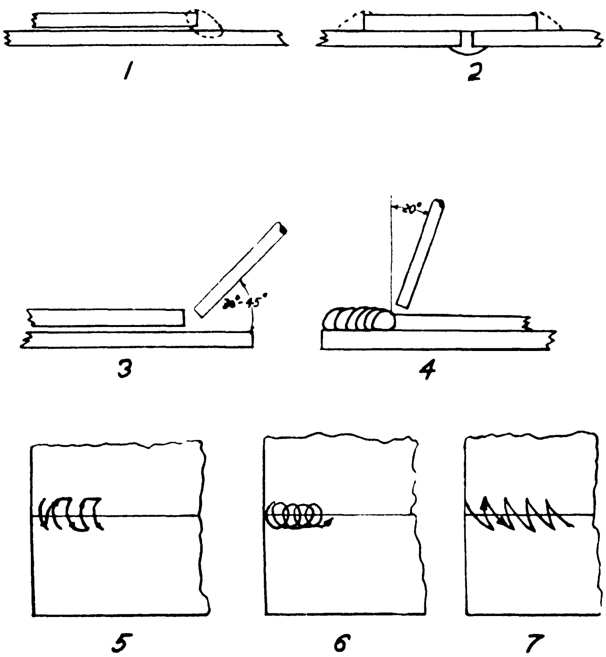


Figure 70. The preparation and arc welding of lap welds. *1* Simple lap; *2* Strap weld; *3* End view of lap weld; *4* Front view of lap weld; *5* Weave motion; *6* Circular motion; *7* Diagonal weave motion

ing, usually without a crackling sound. Further, the color of the arc changes due to the influence of the longer arc on the gas envelope and the slag. By carefully observing these conditions, the beginning arc welder will soon become adept in maintaining the correct arc length.

The bead should be straight. It should have all the same width, the same crown, and it must have even ripples throughout its length. To obtain these features, the arc welder must develop various motions and the proper timing in regard to finishing the electrode. For bead work on thin metal, an electrode motion is not usually necessary. However, as the thickness of the metal increases, the electrode must be moved in some definite pattern to secure the proper fusion of the electrode metal with the base metal and to obtain the electrode bead. Small circular motions are used by some arc welders. Some prefer the back-and-forth motion along with the half-circle across the weld on a 45° angle to it. Some arc welders use the figure-eight motion; some use a triangular motion; while most of them use all of these motions, depending upon the type of seam and the position in which it must be welded. It is essential that the bead have no indications of undercutting, and that thorough fusion is evident along the length of the bead. Undercutting usually indicates that the welder has either been using the wrong electrode motion, or that the machine is out of adjustment. A practical application of these exercises is the rebuilding of worn surfaces in welding maintenance work. Shafting, excavation implements, gear teeth, wheels of various kinds, journals, and so forth very frequently are worn to the extent that they must either be discarded or salvaged. Rebuilding these surfaces by laying arc beads side by side over the light surface in one or more layers and then refinishing has become a large part of the maintenance division of arc-welding. Another application of bead work is hard surfacing or wear-resistant surfacing. Laying beads of special metallic alloys side by side on a soft steel surface enables an arc welder to make those surfaces extremely hard or very resisting to abrasive welding.

79. Arc Welding a Flat Butt Joint

To arc weld two 1/8″ thick, cold-rolled, steel plates together, the operator must adjust the machine to approximately 80-100 amperes. To adjust for the correct amperage, the beginner should start the machine, insert a bare or dusted mild steel 1/8″ diameter electrode in the holder, and strike an arc while watching the ammeter. (Be

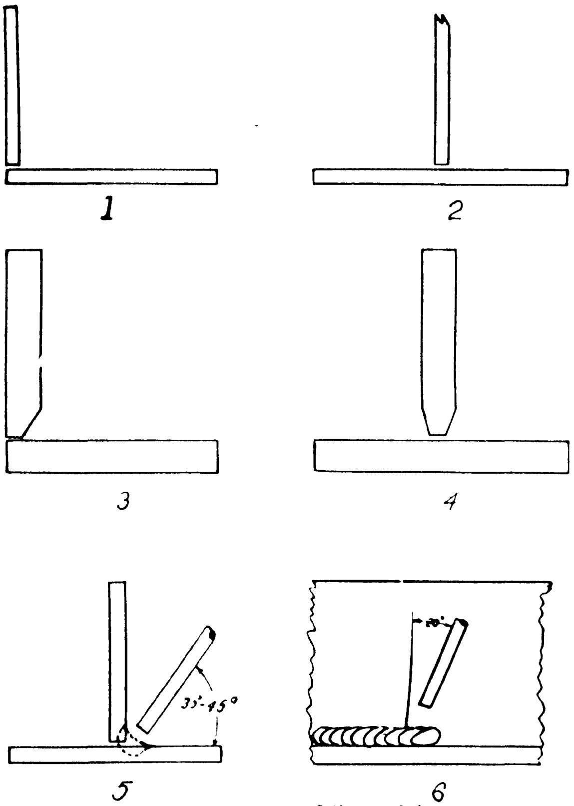


Figure 71. The preparation and arc welding of inside corner and tee weld: *1* Thin metal outside corner weld; *2* Thin metal tee weld; *3* Thick metal inside corner weld; *4* Thick metal tee weld; *5* & *6* Electrode angle for inside corner on tee welds

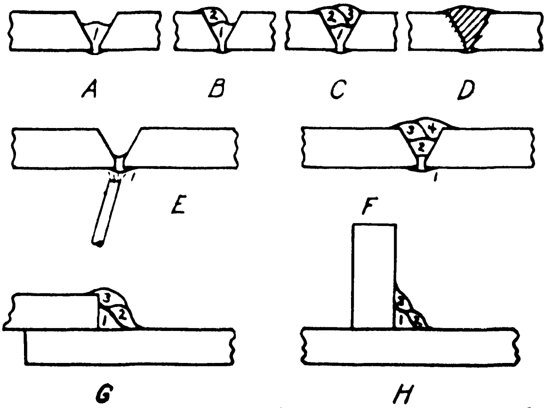


Figure 72. Multiple bead arc welds: *A* First bead (stringer bead), *B* Second bead, *C* Third bead, *D* Finished weld, *E* Overhead weld penetration bead, *F* Finished weld, *G* Three bead lap weld, *H* Three bead tee weld

careful of the arc rays.) It is better to have another person watch the ammeter while the operator strikes the arc. The arc should be emitting the crackling sound when the ammeter is read. (The correct value to be used for the different exercises may be obtained from *Figure 48.*) The closed circuit voltage is read at the same time and should be between 16-24 volts.

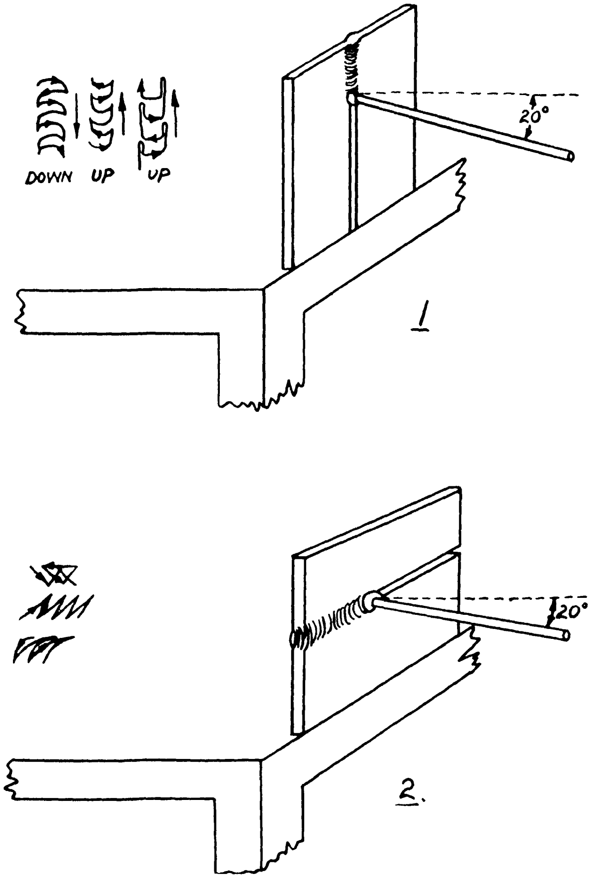


Figure 73. The arc welding of a vertical surface seam. One should use less current and hold a very close arc. Some types of electrodes are better than others for this task. Always use coated electrodes. *1* Vertical seam; *2* Horizontal seam

Place the two pieces on the table with their longer edges touching (butt weld). Allow for metal contraction by "Veeing" the gap lengthwise or by tacking the two pieces at both ends of the joint. Put the shield in place, strike the arc, and reduce the arc length

until the crackling sound is heard. Run the bead across the metal. Use very little motion.

Inspect the weld for smoothness, penetration, air bubbles, fusion, spattering, and added metal. It should have a clean-looking bead. The penetration should just show through the under part of the metal joint; the weld should not be filled with small cavities which

Figure 74. **Making a practice vertical arc weld**
(Courtesy of: Hobart Bros. Company)

would indicate too long an arc; fusion means a good bond between the added metal and the original steel plates; it is indicated by a perfect blend, not by a distinct edge between the added metal and the parent metal. Spattering is the result of too long an arc, or too much voltage and amperage. If the metal is loosely connected to the table, the resulting wandering arc will give the same result; all reversed polarity will cause a spattering arc (grounded, to elec-

trode). Never try to arc weld rusty, dirty, or greasy metals as the arc will be hard to maintain, and the resulting weld will be poor. A steel brush is a handy tool with which to remove rust and dirt from the metal, and one should be placed in a convenient place in the booth. Next practice on thicker metal.

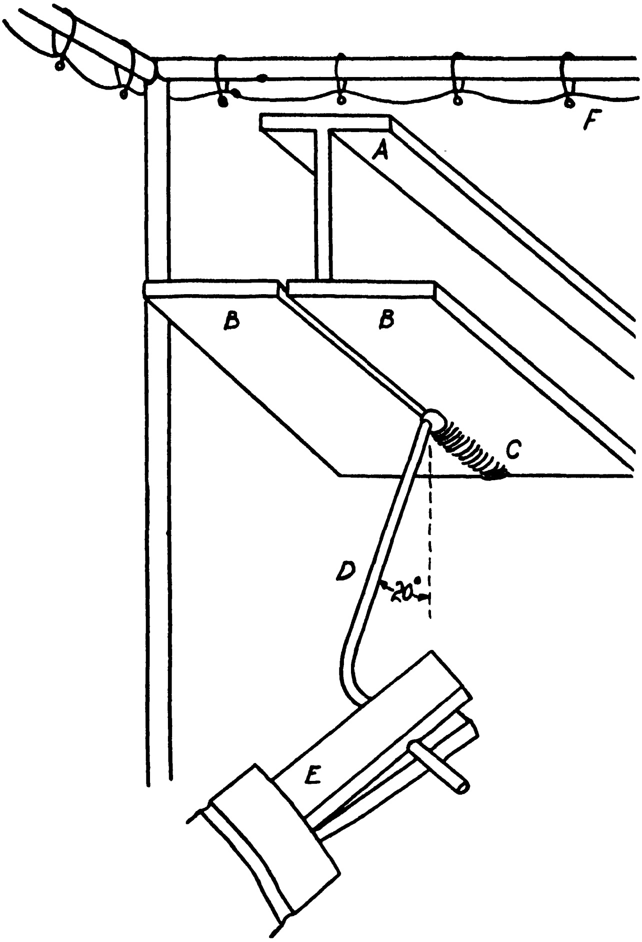


Figure 75. The method of welding an overhead arc weld. The coated electrodes only, keep a very close arc and wear an abundant amount of protective clothing. *A* Fixture, *B* Base metal, *C* Bead, *D* Electrode, *E* Electrode holder, *F* Booth curtain

Procure two pieces of ½″ thick, cold-rolled steel. Grind or cut the metal to a "Vee" (45 degrees) which should extend within 1/16″ of the bottom. Tack the ends, leaving a 1/16″ gap at the bottom of the Vee. *Figure 69*.

This type weld may be tapered, or tacked, like the one in the previous paragraph. The welding may be done in one, two, or three operations. If done in one operation, the welder must use an oscillating motion to distribute the filler metal in the "Vee" and to secure adequate fusion. If two or more beads are used to complete the weld, the operator should clean the first bead before attempting to make the next bead. This weld should be penetrated slightly, and should also be built above the original metal.

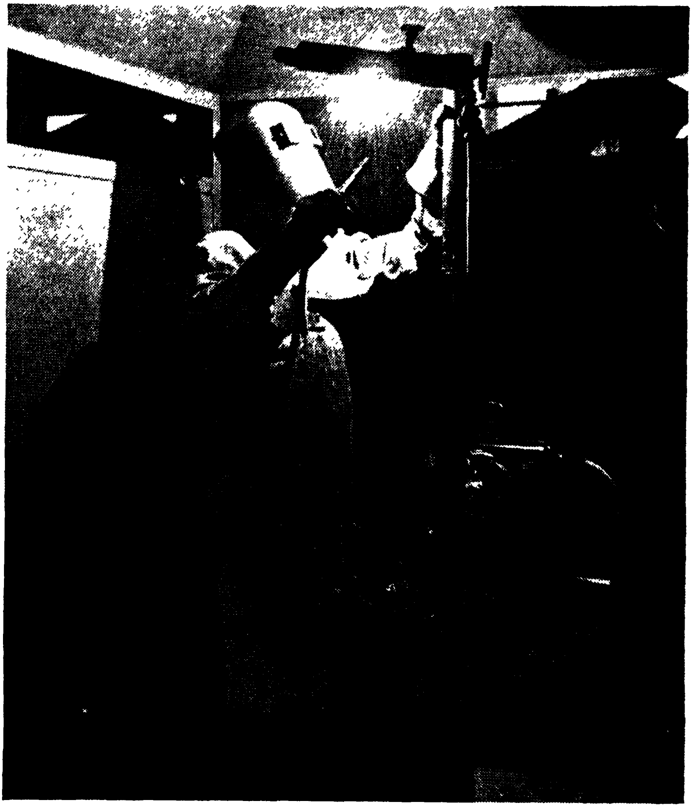


Figure 76. Making a practice overhead arc weld
(Courtesy of: Hobart Bros. Company)

80. Arc Welding a Flat Lap Seam

This type of seam is common although it is not the best strength weld. *Figure 70* illustrates the various lap weld assemblies. To arc weld this seam successfully, one must remember that the piece which is not having its edge welded will require the greater portion of the heat. To distribute the heat, a weaving motion must be used with most of the motion taking place over the bottom piece. The

electrode must be held in a position to point it at a slight angle into the weld. To keep the arc length constant the welder must raise the electrode slightly as the arc travels over the edge of the upper piece. The finished bead must be slightly crowned (convex) and must be straight, even in width, smooth, and clean. It should show good fusion between the bead and the parent metal.

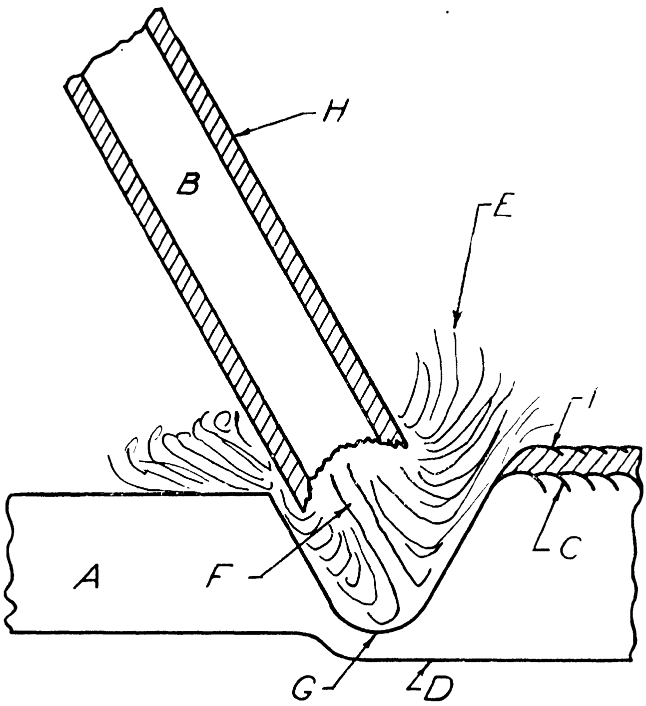


Figure 77. A coated electrode arc weld in the making: *A* Base metal, *B* Electrode, *C* Bead, *D* Penetration, *E* Reducing gas shield, *F* Arc stream, *G* Crater, *H* Coating on electrode, *I* Slag covering of bead

81. Arc Welding a Flat Inside Corner Seam

This weld may be performed with the two pieces forming a seam at their edges, or it may be done with the edge of one piece placed near the middle of the other, forming an inverted "Tee." *Figure 71.* The electrode must be held at an equal angle between the pieces 45°, and should be tilted slightly in the direction the electrode is traveling. The finished weld should be concave (fillet) and should be straight, even in width, smooth, clean, and evenly placed, half on one piece and half on the other piece. *Figure 72.*

82. Arc Welding on a Vertical Surface

Whenever possible a welder should perform the weld in a flat position. In factories, special turntables are built to move the work so that this may be accomplished. However, many welds have to be done in vertical, horizontal, or in overhead positions because of the size of the work or because turntables are not available. These welds must be of the same quality and strength as welds done in a flat position. *Figure 73.*

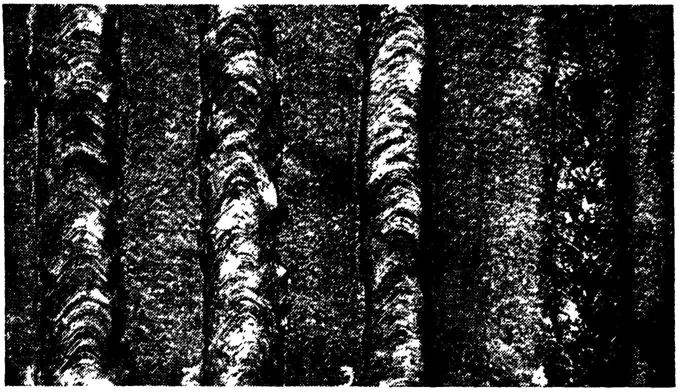


Figure 78. The appearance of finished welds: *1, 2, & 3* Coated welds after chipping; *4* A bare electrode weld
(Courtesy of: General Electric Company)

When welding a vertical seam, the added metal tends to flow down the seam; this must be prevented by pointing the electrode slightly (approximately 20°) upward. Further, a short arc must be maintained, and the motion must be such that the force of the arc will prevent the sagging. *Figure 74.*

When welding a horizontal seam on a vertical surface, the electrode is also inclined upward at the arc to counteract this sagging, and the motion is an inclined weave with the forward motion taking place only at the upper end of the bead. This type of weld also requires a short arc (low arc voltage). One must be sure to eliminate undercutting at the edge of the bead, which is usually the result of excess current for the size of the electrode used.

83. Arc Welding Overhead

This method of arc-welding is the most difficult; it is also dangerous for any welder, not wearing the correct protective clothing. The beginner should first practice making beads in the overhead position before attempting to weld any seams. *Figure 75.* A very short arc must be maintained, and the electrode size must be one

size larger than recommended in *Figure 48.* The usual weaving motion should be used, and the operator will find that, after a few hours practice, the welds become comparable to welds in a flat position. *Figure 76.*

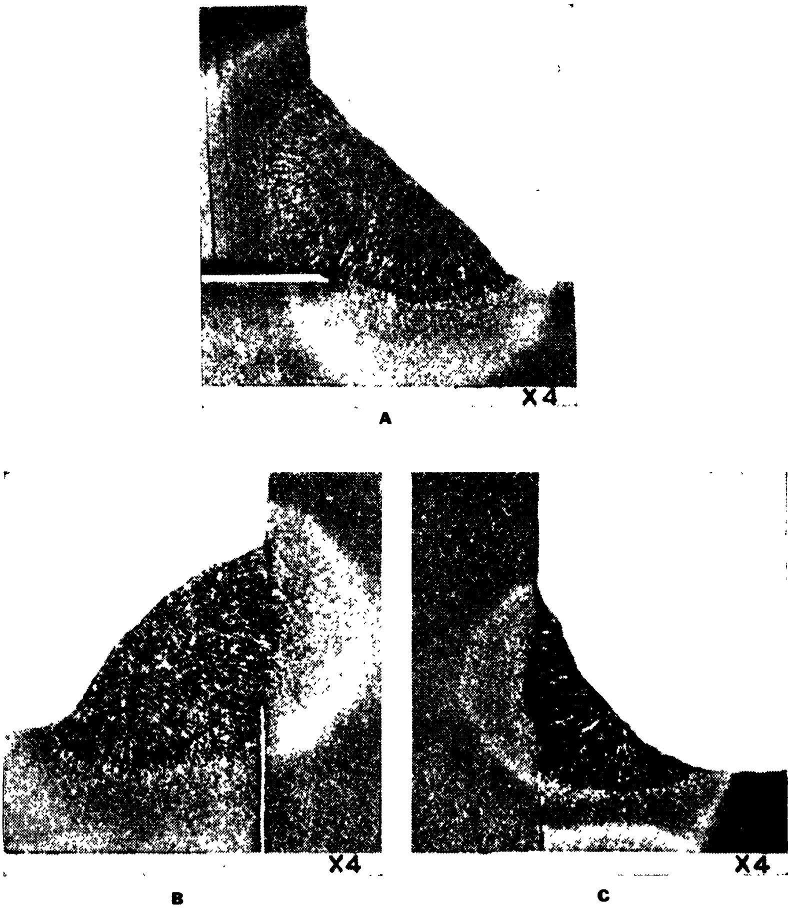
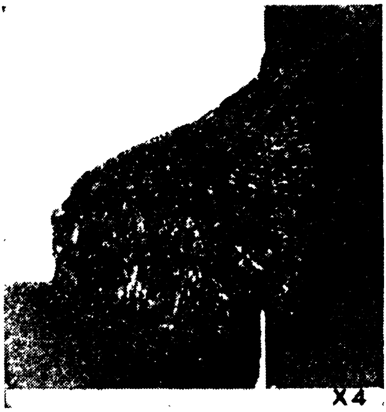


Figure 79. Fillet welds (magnified 4 times): A. Flat face, B. Convex, C. Concave
(Courtesy of: U. S. Steel Corporation)

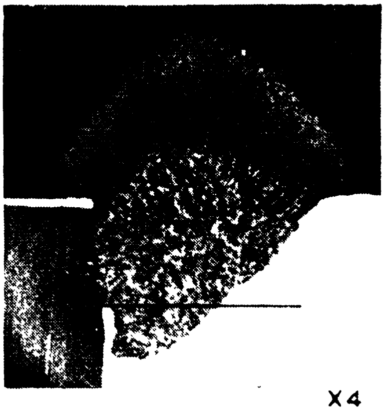
84. Shielded Arc Welding (Fluxed Electrodes)

The beginning welder will find it most economical to practice the first stages of electric arc-welding by using bare or uncoated electrodes. These electrodes are considerably cheaper than the fluxed ones. Bare electrodes will sometimes produce inefficient welds, inasmuch as air is permitted to come in contact with the molten

metal, but the technique used is the same as that to be followed when using the coated electrodes. After reaching the development where the proper bead is maintained in all positions, the student may then use the coated electrodes and practice with them for a short time. It will be found that welding with the coated electrodes



A—Excessively Convex



B—Undercut C—Overlapped

Figure 79A. Fillet welds (magnified 4 times). Unacceptable
(Courtesy of: U. S. Steel Corporation)

will be extremely easy after one has become proficient with the bare electrode.

The shielding material on the fluxed electrode may be applied to the rods in two different manners.

One type of shielded electrode has an impregnated, woven mat (flux) on the rod, which generates neutral gases around the arc flame, preventing the air from coming in contact with the molten

metal, and covering the bead with a slag to protect it from the air while hot. *Figure 77.* The finished weld produced from this type of electrode has excellent qualities from every point of view, such as ductility, density, and smoothness. *Figure 78.*

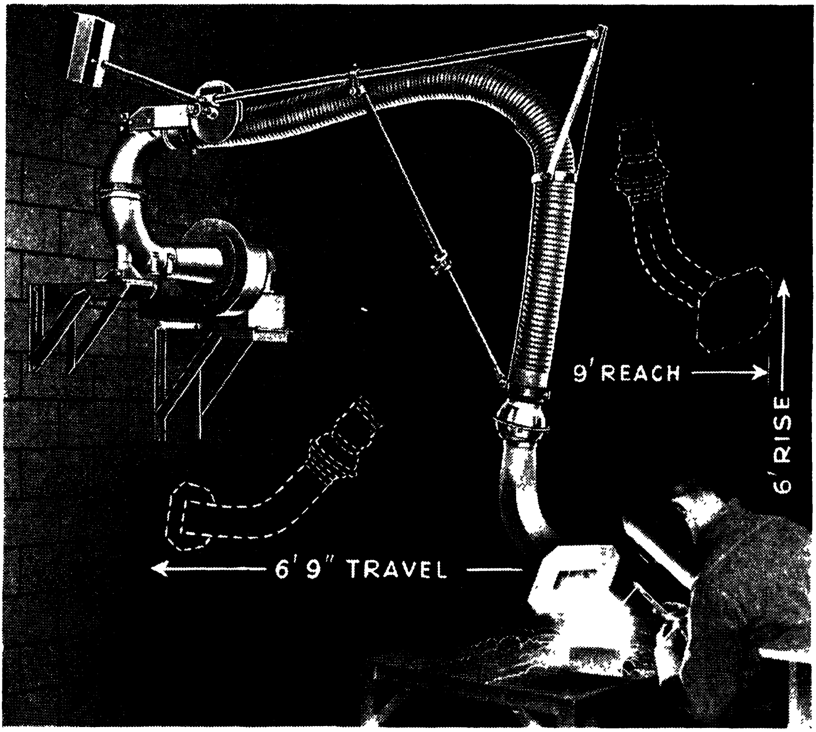


Figure 80. Removing objection gases thrown off by an electric arc. Note the flexibility of the exhaust system
(Courtesy of: Ruemelin Mfg. Company)

Another type of electrode is coated by dipping the rod in a coating material, which adheres to the electrode in the thickness that the manufacturer desires for the rod. This type requires some care in handling in order not to break off the shielding material as the electrode is bent into any special shape for welding in difficult corners. This is especially true for over-head welding because most operators bend the electrode to enable a more comfortable stance, or position. *Figures 79 and 79A.*

When using shielded electrodes in a considerable quantity, special provisions must be made to ventilate the booth or room from fumes which come from the burning of the flux coating. The welder should attempt to minimize these fumes by placing himself in a

position where the fumes will not travel behind the shield or helmet. Spattering of the molten flux sometimes occurs, and it is recommended that the welder thoroughly protect himself with adequate clothing before attempting shielded arc-welding. *Figure 80.*

By means of special fluxed electrodes, practically all kinds of arc welding are feasible, such as, special alloys, aluminum, cast iron, copper, brazing, and others.

85. Review Questions

1. What is the recommended closed-circuit voltage for metallic arc welding?
2. What polarity does anode signify?
3. Is the electric arc used for cutting?
4. Should an arc weld penetrate through the thickness of metal?
5. Does an arc weld usually leave a ripple bead similar to acetylene welding?
6. What is the most popular type of repair-shop, electric-welding machine?
7. Why must one wear gloves when electric arc-welding?
8. Why is No. 10 and No. 12 safety lens used in head shields and hand shields?
9. Is it necessary to vary the voltage for different thicknesses of metal? Why?
10. Why is direct current most commonly used for electric arc welding in the vertical and overhead positions?
11. In what direction does the electricity generally travel (straight polarity) ?
12. What is the distinct indication of the correct arc length when welding?
13. Why is it necessary to keep the arc welding machine free from dust and grit?
14. At what angle should the electrode be held in relation to the metal?
15. How much of the heat used for arc welding is liberated at the electrode?
16. What is the result of maintaining too long a welding arc?
17. Why is it necessary that all the electric connections be tight and clean?
18. What is the function of the coating on a shielded-arc electrode?
19. What is open-circuit voltage?
20. Why doesn't the ammeter register unless an arc is being maintained?

21. What is a reactance coil?
22. What is the purpose of an exciter?
23. What is an average size motor for driving a 200 ampere generator?
24. Why must the cable be super-flexible?
25. What precautions must be taken when attaching the welding cables?
26. What is an electrode holder?
27. Of what is the electrode-holder handle made?
28. Why are some electrode handles water-cooled?
29. Name the two types of arc-welding shields.
30. Describe the results if the lens did not fit tightly into the welding helmet frame.
31. What number safety lens is used in the arc welding shield?
32. Is it important to clean metal before arc-welding it? Why?
33. Describe the clothing to be used when arc-welding overhead?
34. List the specifications for some metallic electrodes.
35. Name the minimum and maximum diameters of carbon electrodes.
36. Carbon electrodes are used for what two purposes?
37. Why are some metallic electrodes flux covered?
38. What is the oldest method of generating electricity for arc welding?
39. Why must the generator be kept clean?

CHAPTER V

ALTERNATING CURRENT ARC WELDING

Alternating current for arc welding has been used for many years, and it has certain characteristics which make this type of welding in certain cases particularly desirable.

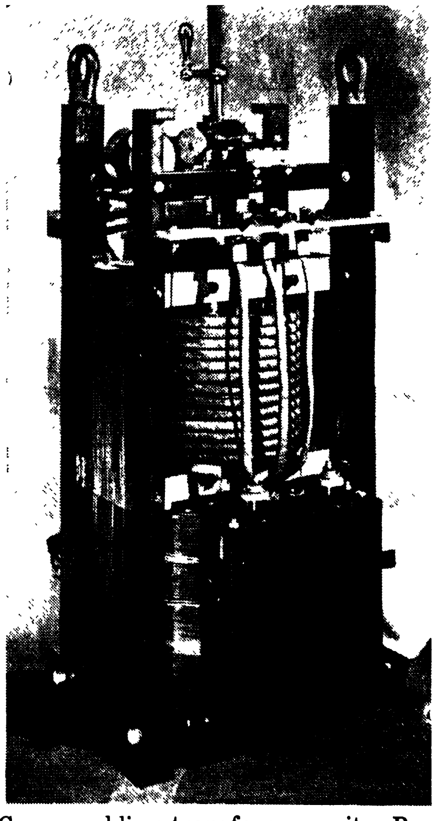


Figure 81. An A.C. arc welding transformer unit. Reactor above while the primary and secondary windings are in the lower part. The handwheel raises or lowers the core of the reactor winding
(Courtesy of: Westinghouse Electric and Mfg. Company)

86. The Alternating-Current, Welding Transformer

The alternating-current welder most commonly uses the transformer to obtain the proper electrical characteristics. The welding transformer has an appearance similar to the usual power transformer. This transformer is wound to step-down the usual power

supply from 110-220 or 440 volts, according to the current available. However, its construction is very carefully engineered to produce good arc characteristics with safety. The transformer consists of a primary circuit, using a single phase current at either of the above voltages. The secondary winding, which is the arc winding, is the step-down type, and reduces the primary high voltage to an open circuit voltage of between 80 to 100 volts, and a closed circuit voltage of between 20 and 30 volts. The amount of current produced for welding is varied either by the use of a resistance in the secondary circuit, or by means of a variable reactance in some part of the

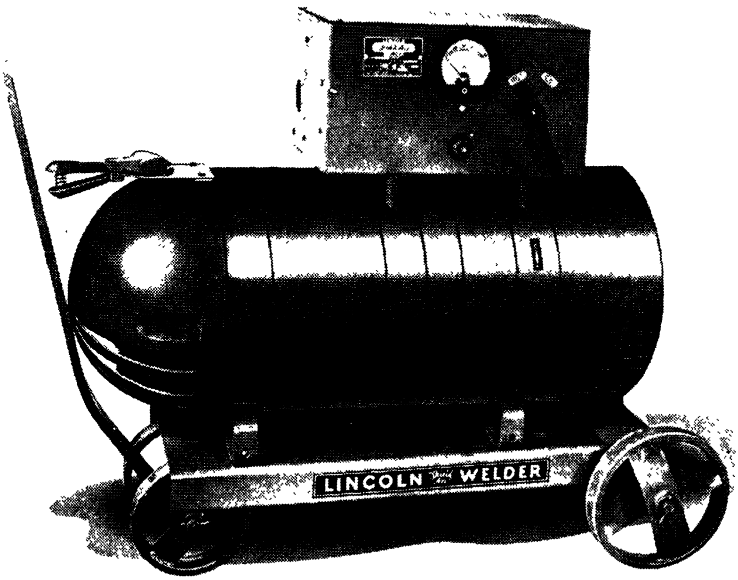


Figure 82. An A.C. arc welding generator
(Courtesy of: The Lincoln Electric Company)

circuit. The reactance may be applied in one of three places: first, the transformer core may be movable; second, the primary winding may be movable; third, the secondary winding may be movable. These transformers must be specially built to guard against a short between the primary and secondary windings, as this condition would be dangerous. The transformer must be specially constructed to eliminate the need for high open-circuit voltage, as this may also be dangerous or uncomfortable. The most popular method of eliminating high open-circuit voltage is to use a high frequency pilot. This is a type of spark coil which momentarily imposes a high frequency voltage of low current across the arc, making it easier for

the operator to start the arc. These transformers are generally mounted in a ventilated steel cabinet with suitable controls and meters as desired. Occasionally, the transformers are mounted on wheels to make them more easily portable. *Figure 81.*

87. Alternating Current Generators

This type of alternating-current, arc-welding machine makes use of a motor-driven, alternating-current generator. This generator is similar to the dynamos used to generate alternating current for domestic and industrial purposes. It may be driven by means of a three phase or two phase alternating-current motor. The generator itself is usually constructed to furnish a high frequency; namely, the frequency of approximately 180 cycles per second, rather than the normal frequency of 60 cycles per second. This higher frequency will enable the operator to maintain a better arc. The generator proper has the field, or stator, windings energized by means of the power current; but the current for arc welding is taken from the armature by means of brushes, ridings, or sliprings. The amount of current available for arc welding is varied by using an adjustable reactance in the welding circuit. Also, the welding circuit has an auxiliary, high-frequency pilot to enable the operator to strike the arc more easily. Such generators usually have incorporated in them a special device which reduces the arc voltage to zero, if the welding circuit is shortened for any length of time. This is to eliminate any danger of burning out the armature windings through excessive, current draw. *Figure 82.*

88. Alternating-Current, Arc-Welding Equipment

A typical transformer type of arc welder is illustrated in Figure 83 and shows the detailed construction of the machine. One may note that there are no moving parts in the apparatus, which is considered one of the biggest advantages of the unit. However, since this machine is a single phased machine, it tends to disturb the electrical power circuit. Because of the low power factor which will be produced on the power circuit used, it will vary noticeably with the power factor of the three-phase circuit to which it may be connected. It is recommended when using an alternating-current machine, that the arc welding leads be of minimum length, inasmuch as the electrical resistance of the cables will increase the difficulty with which the arc is "struck" and maintained. It is necessary that proper air circulation be permitted around the transformer in order to eliminate the danger of overheating the insula-

tion on the windings. The arc welding generator is usually a high speed mechanism, and is usually driven by a three-phase motor, usually operated at 3,600 rpm. The generator and motor are usually mounted on the same shaft, making a unit construction, eliminating extra bearings and a flexible coupling drive. The external appearance of the machine is very similar to the direct-current, arc-welding apparatus, *Figure 84.* It is important with this machine as well as with other arc welders, to keep the arc cables as short as

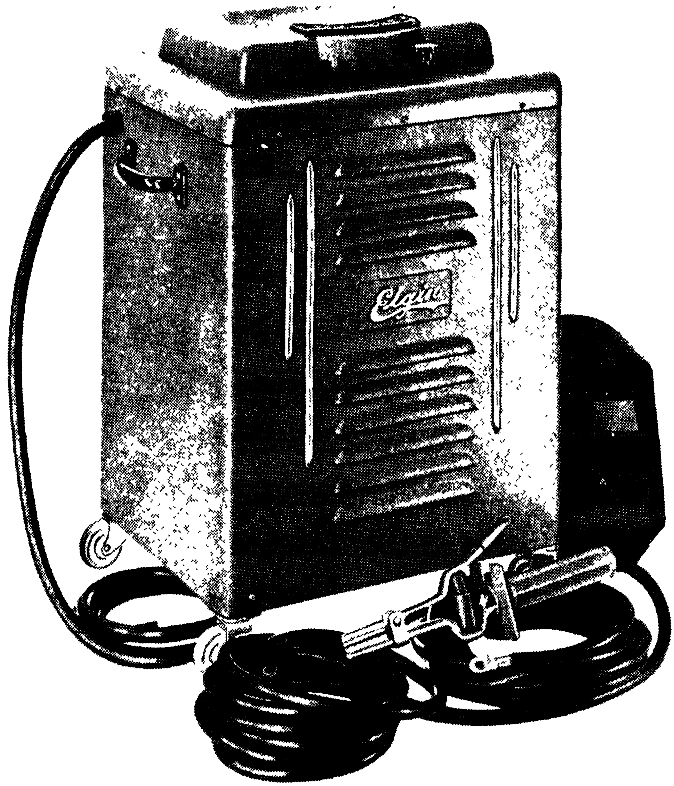


Figure 83. A complete A.C. transformer type arc welder. The adjustment handles are located at the top. This machine has a capacity of 160 amperes
(Courtesy of: Borm Manufacturing Company)

possible. The machine should not be worked in a damp place, nor should it be allowed to accumulate dust. The use of high-pressure air is one of the best means of removing dust from the internal mechanism. Under no circumstances should one attempt to weld with the arc-welding cable looped around the machine, as this con-

dition produces electro-magnetic fields which may seriously hamper and injure the machine. It is best to eliminate the danger of receiving electrical shocks from the arc-welding circuit of an alternating-current machine, although these shocks are not generally considered dangerous. The shock may be annoying enough to make one move, or jump, and injure himself in some other manner. This may best be done by grounding the arc welder, using a completely insulated electrode holder, and arranging to have the operator stand on a dry wooden floor.

89. Striking An Alternating Current Arc

The practice of arc welding with an A.C. machine is very similar to the D.C. type. It is a little more difficult to strike the arc with the A.C. type because of the tendency of the apparatus to break the arc on the change of the cycle (120 times per second in a 60 cycle circuit). Special provisions are therefore provided to reduce the no-current interval. As mentioned previously a high frequency current is sent across the gap at first to enable the arc to be more easily maintained. This high-frequency, super-imposed current is automatically discontinued, the moment the operator manages to hold the arc for a few seconds. The operator will find the two motions recommended in *Chapter 4* should also be used for A.C. work. If the arc breaks continually, regardless of how careful the operator may be, it is probably due to the too-low current-adjustment of the machine. If the electrode spatters excessively, and if it turns red hot while one is welding, the current is excessive. The operator will find that once an arc is maintained for a time, the arc length can be increased considerably over the length one may use in D.C. work. Arcs of one to two inches in length are not unusual although impractical for welding purposes.

90. Alternating Current Arc Characteristics

The A.C. arc does exactly what the D.C. does, but some of its behavior varies. By having a change in current direction at extremely fast intervals the problem of magnetic blow is eliminated. The melting of the electrode is somewhat faster than when one uses straight D.C. polarity, and is a little slower than reversed D.C. polarity. The heat distribution is 50% at the electrode and 50% at the metal. The continual reversal of current makes it necessary to use coated (fluxed) electrodes when doing A.C. arc welding.

91. Alternating Current Welding Practice

There has been a steady increase in the use of A.C. arc welders

by both manufacturers and shops. The initial cost of the equipment and the elimination of magnetic blow is probably the most important reason for this. Being able to produce welds in corners, at edges, and in recesses without trouble enables a welder to produce much better welds in these places. However, the weld should be performed in a flat position, if possible. If the weld must be done in a vertical or overhead position, it will be advisable to use a D.C. machine. The metal for A.C. welding should be prepared for welding as explained in Paragraph 79 and the appearance of the weld should be similar to a D.C. machine weld. The same motions, the same arc length, the same current capacities, and electrode sizes are used as in D.C. arc welding. A much longer arc can be drawn when using A.C. equipment than with D.C. A welder can therefore easily use too long an arc, thereby increasing the chance of oxidizing.

92. Safety in Handling A.C. Arc Welding Equipment

There is not much danger of electrical injury when one uses automatic, Underwriters Laboratory-approved A.C. equipment. The high frequency A.C. generator is also completely safe to use. *Figure 84.* However, the power input circuit, if it is of the 220 or 440 volt, may injure one, especially if the shock is across the body affecting the heart.

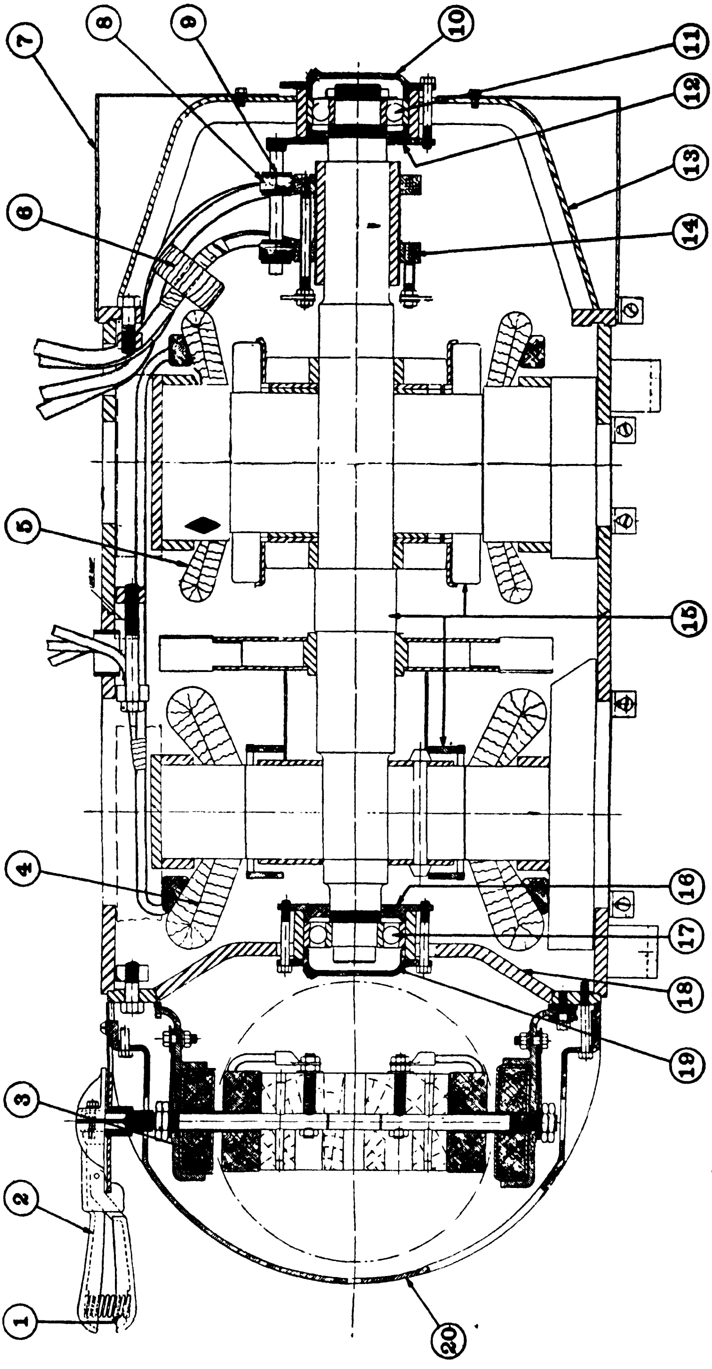
If the A.C. transformer is used, one may encounter danger if using absolete, home made, or non-Underwriters Laboratory-approved-equipment.

The possibility of burns and "flashes" occurring must be handled in a manner similar to the method outlined in Paragraph 71. If one has received a strong electric shock, the proper first aid treatment is as follows:

1. Remove cause of the shock
2. Call a doctor
3. Apply artificial respiration
4. Keep the victim warm
5. Apply stimulants (smelling salts)
6. Make the victim lie down and rest

93. Automatic A.C. Arc Welding Machines

The automatic A.C. arc machine is almost identical with the D.C. type. The work is either moved under the stationary arc machine, or the machine travels on tracks along the weld. Variable speed motors control the speed of travel, the feeding of the electrode and



1. Spring, for Current Control Handle
2. Current Control Handle Assembly
3. Current Control Assembly
4. Stator Coils, Motor End
5. Stator Coils, Welder End
6. Current Transformer
7. Outer Cover, Welder End
8. Brush
9. Brushholder Assembly
10. Outer Dust Cap, Welder End
11. Bearing, Welder End
12. Inner Dust Cap, Welder End
13. End Bracket, Welder End
14. Slip Ring Assembly
15. Rotor and Shaft Assembly
16. Inner Dust Cap, Motor End
17. Bearing, Motor End
18. End Bracket, Motor End
19. Outer Dust Cap, Motor End
20. End Shield

Figure 84. A complete A.C. generator type arc welder, 180 cycles, 200 to 600 amp. capacity

(Courtesy of: The Lincoln Electric Company)

flux, and also some apparatus (timing) is used to strike the arc. This type of welding lends itself to long straight seams or regular curves, or places where there are a number of similar welds to be made.

94. Alternating-Current, Arc-Welding Accessories and Supplies

The accessories and supplies used for A.C. arc-welding are much the same as those used in D.C. welding. Helmits, cables, gloves, aprons, benches, booths, "C" clamps, chipping hammers, files, chisels, wire brushes, etc., are all the same. The electrodes are usually specified as being especially made for A.C. welding because of the rate of electrode deposit when using 50-50 heat distribution. A typical A.C. coated electrode has the following specifications:

1. Diameter
2. Length
3. Current
4. Plate thickness
5. Coating specifications

95. Review Questions

1. What type transformer is used in A.C. machines?
2. Why is a special insulation necessary for A.C. transformers?
3. Explain the purpose of the high-frequency arc producers.
4. How are these transformers cooled?
5. What frequency is usually produced by an A.C. generator?
6. What precaution is incorporated in an A.C. generator to protect the winding when the machine is short circuited?
7. Under what conditions does an A.C. arc welder perform to the greatest advantage?
8. Why shouldn't one loop the welding cables around the A.C. machines?
9. What is the proportion of heat released at the electrode and the work when A.C. arc-welding?
10. Which machine can maintain the longest arc, an A.C. or a D.C.?

CHAPTER VI

ELECTRIC RESISTANCE WELDING PRACTICE EQUIPMENT AND SUPPLIES

Electric resistance welding finds a variety of welding applications, and it is known under a variety of names such as spot welding, shot welding, gun welding, and flash welding.

The fundamental principle upon which all resistance welding is based is that when a heavy current is sent thru a metal, it heats the metal. By applying very high currents, and at the same time maintaining a heavy pressure upon two pieces of metal, the resulting high temperature along with the pressure will weld the metals together.

This type of welding lends itself particularly well to all forms of automatic production.

96. Principles of Electric Resistance Welding

When one passes a current of electricity thru two pieces of metal that are touching, the local high resistance generates or produces a high temperature. If enough current is used, the metal will become plastic, and then molten. If the pieces are pressed together while their surfaces are plastic, or molten, the two pieces will fuse into one piece. If the metal is forged, or upset, while plastic (if the shape is changed), the metal will retain its physical properties because of the rapidity with which such operations are accomplished. The joint is considered an extremely clean one, and the physical properties of the seams are as good as any type of weld.

97. Types of Electric Resistance Welding

There are several types of resistance welding based on the above principle. *Figure 85.* Some of the more common types are as follows:

A. Spot welding see paragraph 100.
B. Butt and Flash Welding see paragraphs 103 and 104.
C. Seam Welding see paragraph 105.
D. Projection Welding see paragraph 106.
E. Shot and Gun Welding see paragraph 101.
F. Upsetting see paragraph 107.

All of these operations are fundamentally the same, but the preparation of the metal is different, and the construction of the machines differs.

The four most important variables are:

1. The duration (time) of current flow.
2. The pressure forcing the two pieces together.
3. The amount of current.
4. The area of contact through which the current flows.

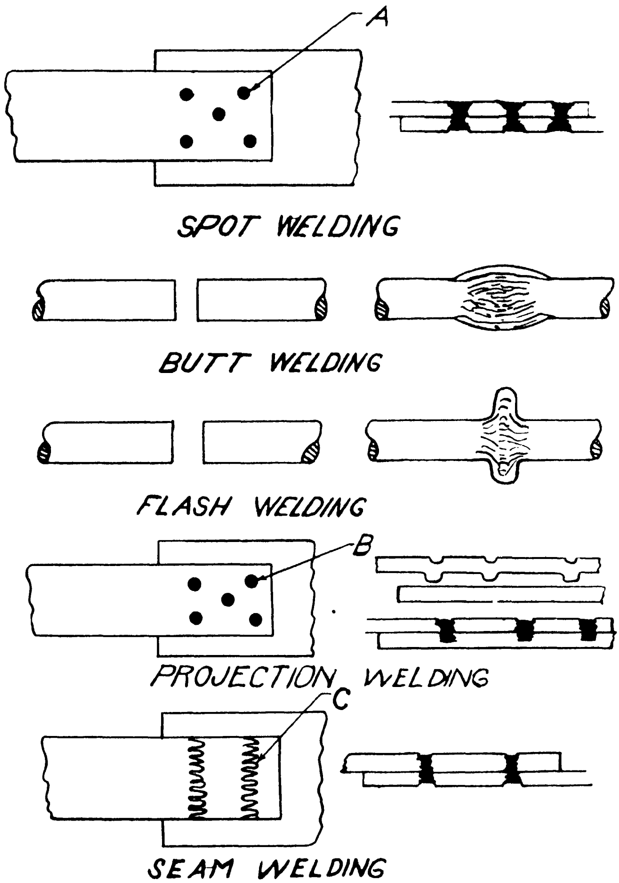


Figure 85. Types of resistance welding: A. Spot welds, B. Projections, C. Track of the roller

98. Transformers

Electric-resistance welding-machines use transformers which consume the usual voltage and current, provided by the power companies. These machines deliver a high amperage and low voltage

current for use by the welding machine. This transformer is commonly called the "step down" type.

For example, it will transform 20 amperes at 110 volts to 200 amperes at 10 volts or 1,000 amperes at 1 volt. Most of these transformers are adjustable. These transformers must use and produce A.C. current. This prevents them from being used on direct current lines.

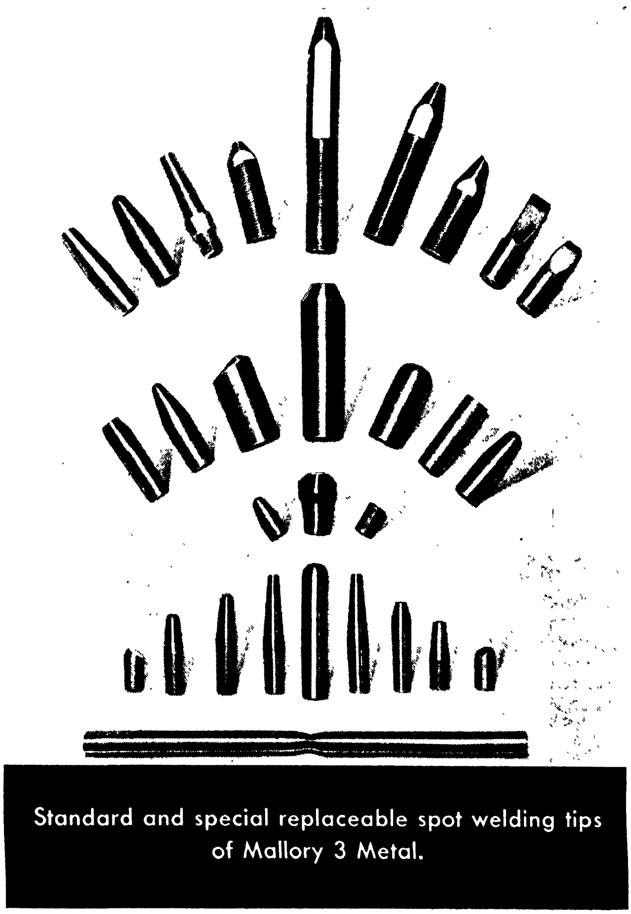


Figure 86. Resistance welding electrodes
(Courtesy of: P. R. Mallory and Co., Inc.)

99. Electric-Resistance Welding-Machines

The construction of all electric-resistance welding-machines is quite similar. The major difference is between the various types of construction of the jaws or mechanisms which hold the object or

objects to be welded, and the shape of the metal to be welded. The machines may be divided into two main classes:

A. The manual machine.

B. The automatic machine.

The manual machine requires good judgment on the part of the operator for good results. The same machine may be used for a variety of different jobs with only minor adjustments. The automatic machine is usually designed for one particular job, and all the movements and the timing are automatic. The operator has only to see that the raw materials are fed to the machine properly.

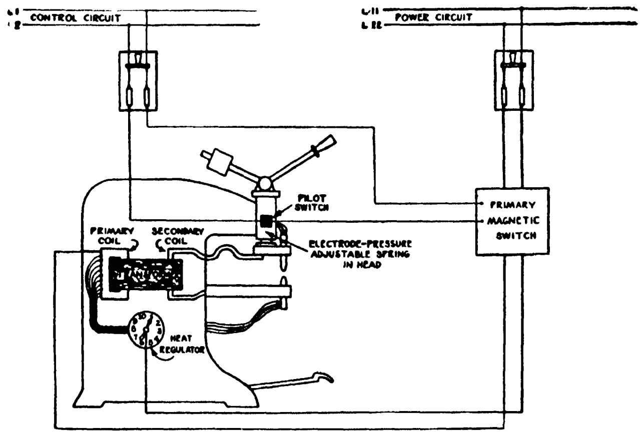


Figure 87. Resistance Welding mechanism
(Courtesy of: The Electric Controller and Mfg. Company)

The various parts of the manual machine are:

A. Frame
B. Transformer
C. Welding arms or electrodes
D. Manipulating mechanisms
E. Control switches

The transformer is one special construction and usually has several taps or adjustments. It may be either air-cooled or water-cooled. The secondary usually consists of one loop of laminated flat copper strips. The ends of these strips are soldered, bolted, or brazed to the electrode arms of the machine.

The welding arms and manipulating mechanisms are different for each type of electric-resistance welder. However, each one usually uses foot power to press the parts together; or a foot-operated switch controls electro-magnets; or air pressure pistons perform this work. The manipulating mechanism also operates the welding current switch; as the mechanism acts, the switch is simultane-

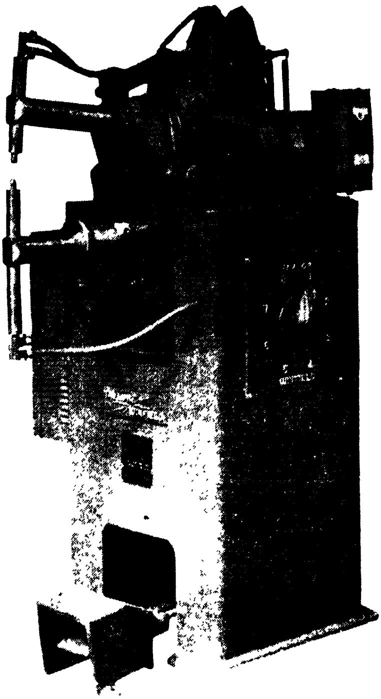


Figure 88. An automatic timing device for a Resistance welder. Note the motor and control in upper right corner
(Courtesy of: The Taylor-Winfield Corporation)

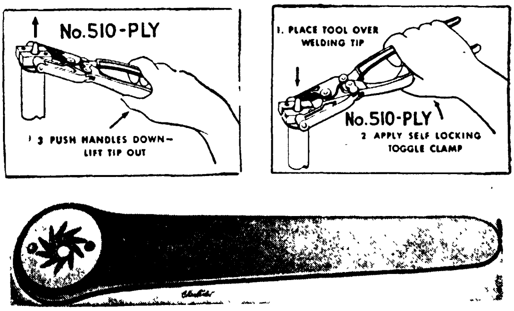


Figure 89. Tools for cleaning tips and removing taper tips
(Courtesy of: Eisler Engineering Co., Inc.)

ously turned on and off at the correct moment for corresponding positions of the clamping arms or electrodes. *Figure 86.* The control switches are manual, primary-circuit switches and are specially constructed to close at the porper time, and to give the correct amount of current (time). The National Electric Manufacturers Code requires that all code regulations be observed when connecting

this machine into the power line. The welder switch usually has large copper contacts which may be easily cleaned, and are adjustable both for wear and for correlating their timing with the movement of the welding electrodes or points. *Figure 87.*

The various parts of the automatic machine are similar to the manually operated machine, with the exception that the movement of the electrode arms and the contacting of the switches is all performed automatically. Electrically timed electro-magnets, hydrostatic pressure, or air pressure valves do all of the operations. Once a machine is timed correctly for a certain operation, the above devices eliminate the human element, and the machine will continue to produce identical welds. *Figure 88.*

The electrodes for these machines are commonly made of hard copper, although for many applications, Elkonite, an alloy of copper and tungsten, is used. Some machines use a silver-copper, alloy electrode. The copper is for conductivity, while the tungsten imparts hardness to the alloy. These electrodes are obtainable in various sizes and forms. It must be remembered that these electrodes must be kept very clean and correctly shaped if they are to produce good results. *Figure 89.*

Thickness 2 Pieces		KVA	Depth of Throat
Ga.	Inches		
14	.078	15	8
14	.078	15	14
16	.063	. .	20
11	.125	20	8
11	.125	20	14
13	.093	. .	20
10	.141	28	10
10	.141	28	14
11	.125	. .	20
7	.187	35	10
7	.187	35	14
9	.156	35	20
3	.250	50	10
3	.250	50	14
5	.218	50	20

Figure 90. A table of spot welding data for Senior E2 Federal Spot Welder
(Courtesy of: The Federal Machine and Welder Company)

100. Spot Welding Equipment

This type of resistance-welding consists of welding small spots on two sheets of sheet metal. It is used extensively on steel and may

also be used for a variety of other metals, such as stainless steel, aluminum, and copper. A small spot of the metal is clamped between two carefully shaped and properly sized electrodes. The current is then turned on for just a few seconds, and the pressure fuses the two sheets together at the spot, just as the metal reaches

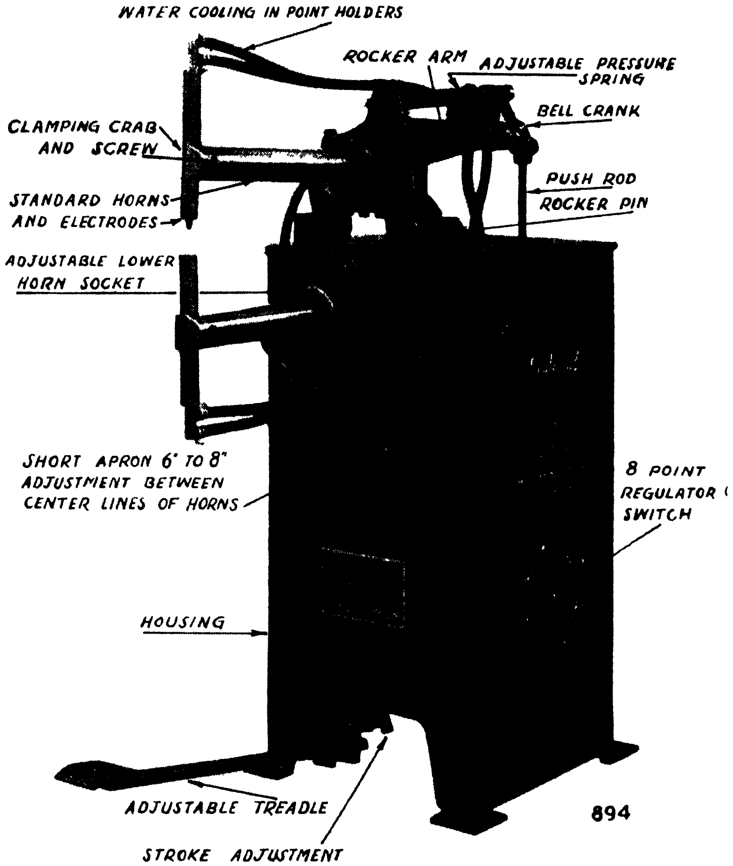


Figure 91. A small spot welder
(Courtesy of: The Federal Machine and Welder Company)

the plastic stage. This type of welding applies only to lap welds, that is, the metal sheets must be lapped, one over the other.

The pieces do not have to be of the same thickness to be successfully welded. The amount of current varies between 100,000 amperes per square inch to 200,000 amperes at the electrodes. The transformer is rated in KVA which is approximately 300% of the KW of the unit. KVA means the Kilo, Volt, Ampere rating of the

machine. For example, if a transformer consumes 35 amperes at 220 Volts, its rating is $\dfrac{35 \times 220}{1000} = 7.7$ KVA.

A table of the variables for spot welding various thicknesses of metals is shown in *Figure 90.* Spot welders may be obtained in a variety of styles, varying from small bench spot welders to large

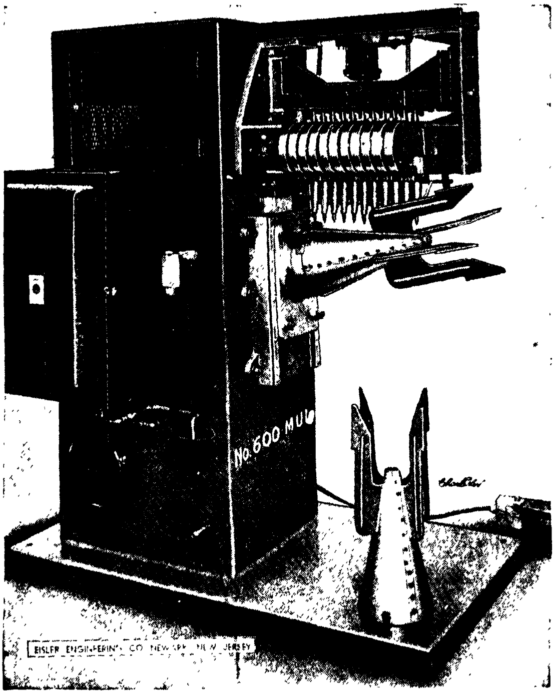


Figure 92. A large spot welder
(Courtesy of: Eisler Engineering Co., Inc.)

multiple automatic machines. *Figures 91 and 92.* Note that the electrodes are practically always water-cooled and that they come in various lengths and shapes. *Figure 93.*

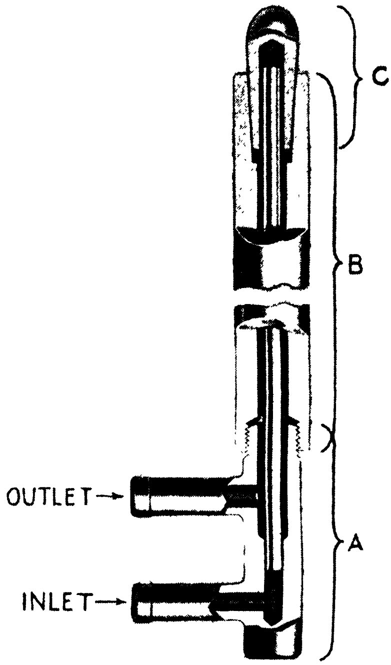
101. Gun Welding Equipment

A special application of spot welding is the use of a portable spot-welder, supported from over head and operated by air pressure. *Figure 94.* The operator merely puts the fixed electrode on the spot to be welded, and presses a trigger; the air pressure presses the moving electrode into place, and also times the electrical current. This welder can produce a great number of spot welds on an irreg-

ular shaped article very quickly. *Figure 95.* This tool is used extensively in automobile body manufacturing.

102. Shot Welding Equipment

Shot welding is identical with gun welding with the exception that a very high current is used for extremely short periods of time ($\frac{1}{100}$ second). It is used extensively for spot welding, stainless steels, aluminum, etc.



The Replaceable Tip (C) is made with a standard taper and fits tightly into the holder. (B) The water cooling hole runs through the shank practically to the end of the tip, insuring cool operation at all times. The electrode holder is made of copper and varies with machine and work. The holder and water cooling attachment lasts for years. The water cooling attachment (A) has both an inlet and an outlet for the water, screws into the electrode holder.

Figure 93. A resistance welding electrode: A. Holder and water cooling attachment, B. The shank, water cooled, C. The replaceable tips
(Courtesy of: P. R. Mallory and Co., Inc.)

103. Butt Welding Equipment

Butt welding consists of touching the end or edges of two pieces of metal; after the current passing between the two has heated the edges to a plastic state, the two pieces are slowly pushed together. This is a new improvement of the blacksmith's weld. As this weld

has a few impurities, it is considered satisfactory for only certain applications. The machine uses the same type of transformer as the spot welder, but the electrodes in this case are vises, one moveable, and one fixed. The ends of the metal must be clean for satisfactory work. *Figure 96* shows the basic action of the butt welder, while *Figure 97* illustrates a typical butt welder machine. *Figure 98* shows the power required and the time needed for butt welding a ½″ round bar.

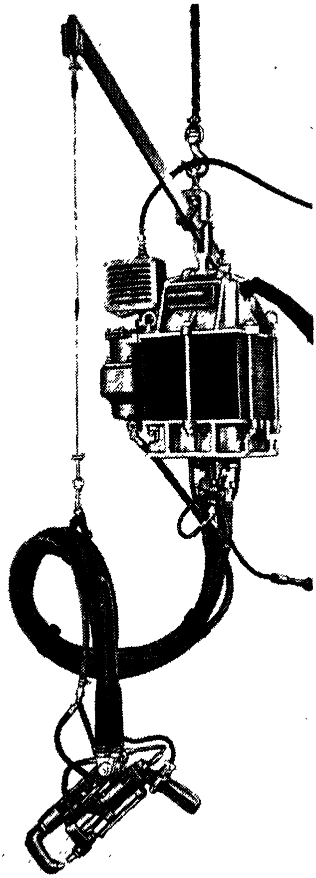


Figure 94. A suspended type gun welder
(Courtesy of: Progressive Welder Company)

104. Flash Welding Equipment

Flash welding is an improved form of butt welding. It is set up exactly the same as the butt-welding machine, but the metal is placed to provide a small gap causing a small arc. After the ends

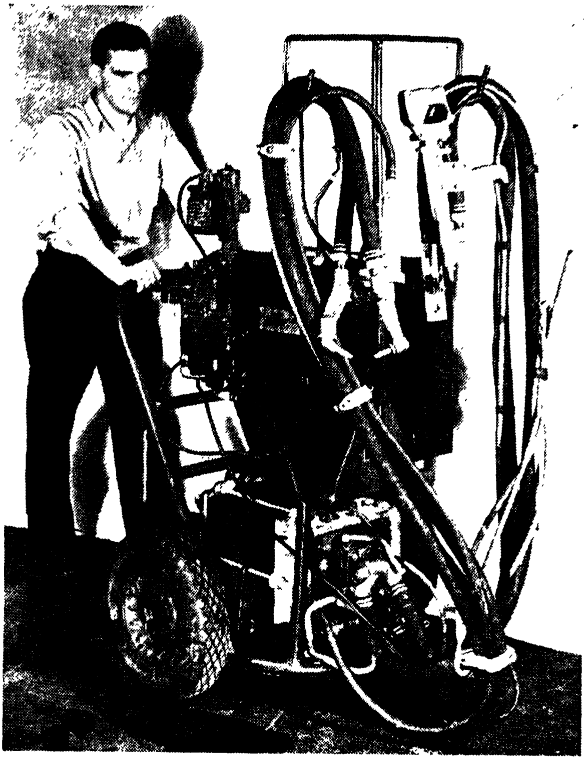


Figure 95. A portable welder. Showing the pincer type and push type gun connected to one portable transformer
(Courtesy of: Progressive Welder Company)

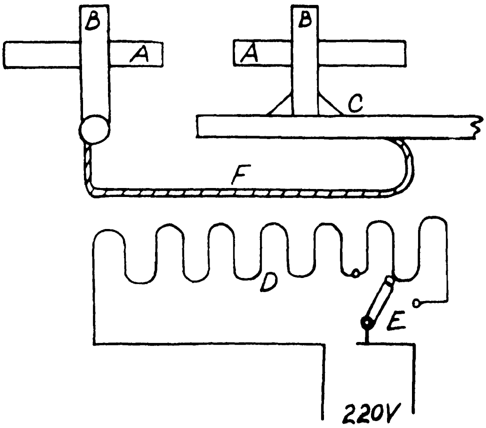


Figure 96. Butt welding principles: A. Metal being butt welded, B. Electrode clamps, C. Movable bead, D. Primary transformer winding, E. Transformer adjustment, F. Secondary transformer winding

are molten, the two pieces are quickly pushed together. This action forces the molten metal to the surface (causing the flash), and brings clean plastic metal into contact. Further the metal is forged

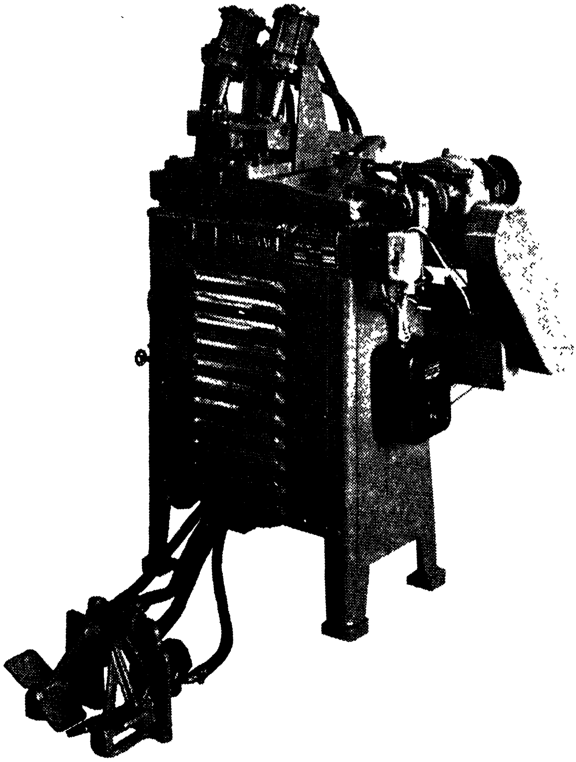


Figure 97. A butt welder
(Courtesy of: National Electric Welding Machines Company)

For ½ Sq. Iron Bars

KW	Time in Seconds	Distance Between Grips
19	3	0.79
14	6	1.6
12	9	2.4
10	11	3.2
8	14	3.9
7.5	17	4.5
7	20	5.5

Figure 98. A butt welding table
(Courtesy of: P. R. Mallory and Co., Inc.)

and worked during the push-up action. *Figure 99.* A table of Flash Welding data is shown in *Figure 100.* The appearance of a flash-welding machine is very similar to a butt-welding machine.

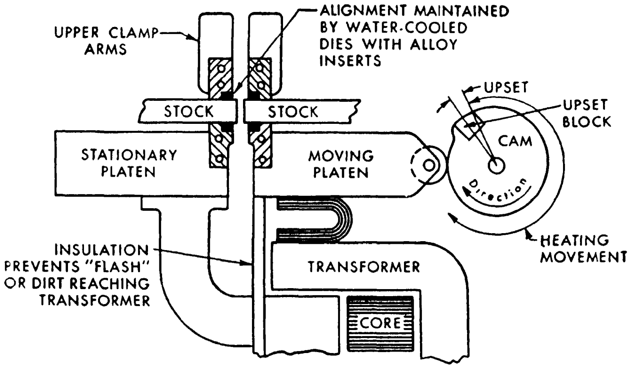


Figure 99. Diagrammatic view of a flash welder
(Courtesy of: P. R. Mallory and Co., Inc.)

Cross Section Sq. In.	Average Welds Per Hour	Trans-formers Capacity KVA	KVA Required	KW Hrs. per 1000 Welds	Push-up Pressure
1/8	600	5	5	.5	75
1/4	500	15	10	1.6	150
3/8	300	15	3	4.5	350
1/2	400	30	25	6.9	800
5/8	300	30	30	15.	1225
3/4	200	30	30	20.	1750
1	150	100	60	34.	3150
1 1/4	100	100	80	55.	5000
1 1/2	75	150	125	79.	7000
1 3/4	60	250	200	125.	9600

Figure 100. Flash weld table
(Courtesy of: P. R. Mallory and Co., Inc.)

105. Seam Welding Equipment

A special form of the spot welder uses two rollers as electrodes. These rollers press two pieces of metal together and roll slowly along the seam. A continuous current is passed between the rollers welding the two pieces with a continual weld. *Figure 101.* The machine must be carefully timed to secure good results, while the cooling of the rollers must be continuous.

106. Projection Welding Equipment

Another type of spot welder is the machine which welds two

pieces of metal, one having small projections pressed into it, extending toward the other piece. When the two pieces are pressed between two electrodes and the current turned on, the projections are fused into the other piece. This method speeds the welding, but requires the extra operation of pressing the projections into the metal.

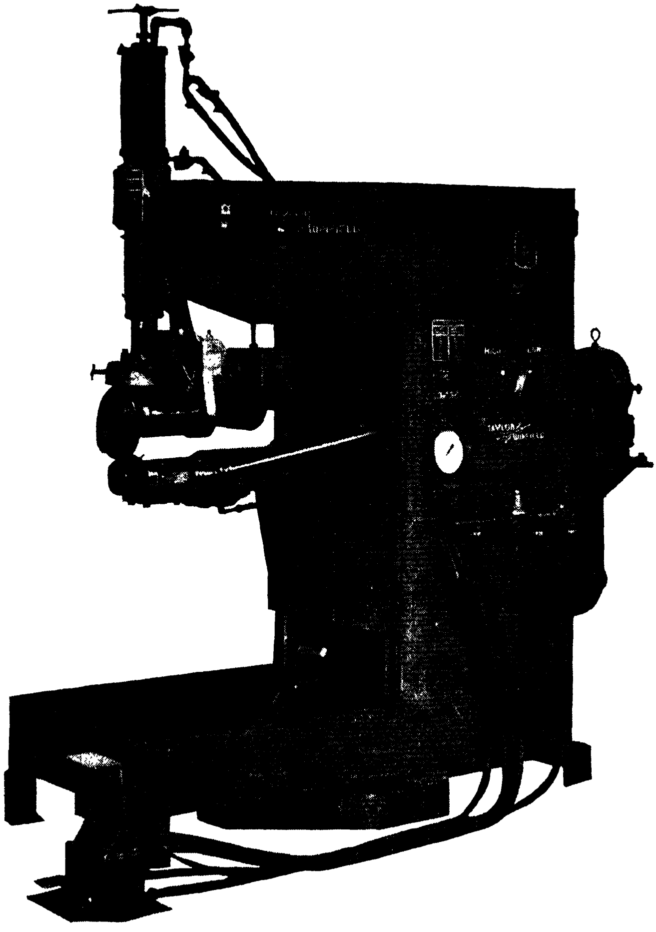


Figure 101. Seam welding machine
(Courtesy of: The Taylor-Winfield Corporation)

107. Electric Upsetting Equipment

A novel use of electric-resistance heating is to pass a high current through a piece of metal located in a jig. After a few seconds, the temperature of the metal is such as to permit the jig to form the metal easily into practically any shape desired.

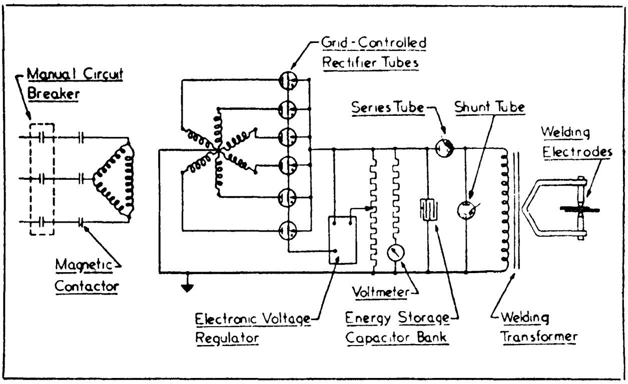


Figure 102. Schematic diagram of a capacitator type spot welder
(Courtesy of: The Federal Machine and Welder Company)

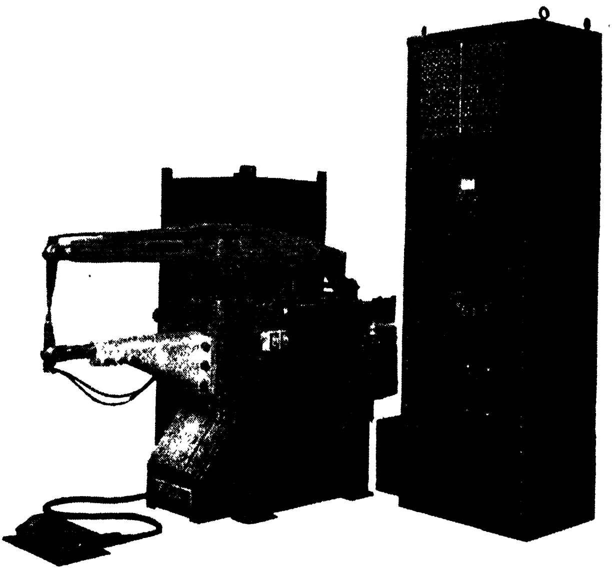


Figure 103. A capacitator spot welder for aluminum alloys
(Courtesy of: The Federal Machine and Welder Company)

108. Spot Welding Aluminum Alloys

A recent development accelerated by the National Defense activities is the resistance welding machine for spot welding aluminum. An extremely accurate mechanism to control the energy dis-

charge and time of discharge was developed. There are several types of resistance welders developed to do this work.

A. The auto-transformer type B. The electro-magnetic type
C. The electro-static type (capacitator)

The capacitator type is most used. Its principle of operation depends upon electrical condenser action. An accurate timing device provides for charging a condenser and then directing the discharge through spot welder points and the metal to be welded. The electrical circuit is clearly indicated in *Figure 102.* The control or timing device, makes use of vacuum tubes and is popularly known as electronic control. *Figure 103.*

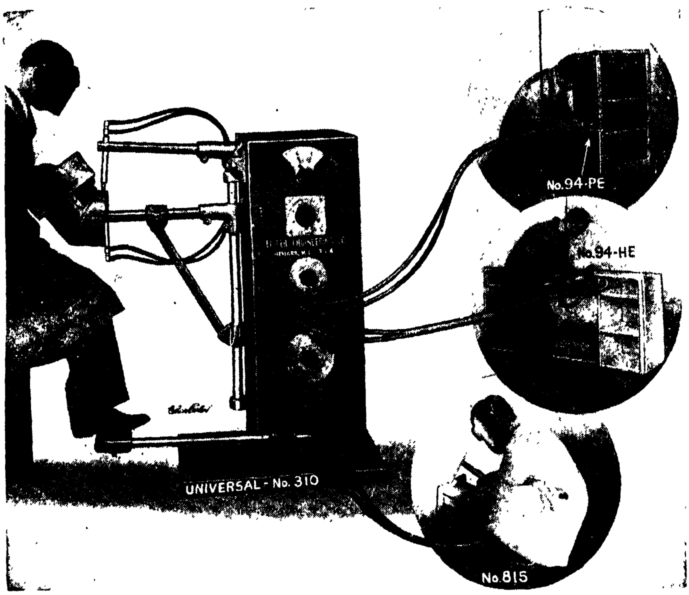


Figure 104. A universal electric welder: 815. Arc welder, HE. Gun welder, PE. Gun welder
(Courtesy of: Eisler Engineering Co., Inc.)

109. Safety in Handling Resistance Welding Equipment

The greatest dangers encountered in resistance-welding are: electrical shock, flying sparks, and injury from moving machinery. As electrical shocks can result only from the primary circuit, only a specially trained electrician should work on the primary circuit. The worker should stand on a dry floor; then there can be no danger from shock from a grounded primary. If Underwriters-Laboratory-approved equipment is used, there is little danger from electric shock. The welder, or operator, should wear gloves and goggles to protect himself from the flying sparks. Power driven machinery,

when used with resistance welders, should be provided with all the safeguards possible. See paragraph 71 for first aid instructions on electrical shocks.

110. Resistance Welding Practice

Automatic, resistance-welding machines are accurately set up by specially trained mechanics, who are usually trained by the manufacturers of the equipment. Amount of current, size of contact area, time, and pressure are the main items one must regulate to obtain good results.

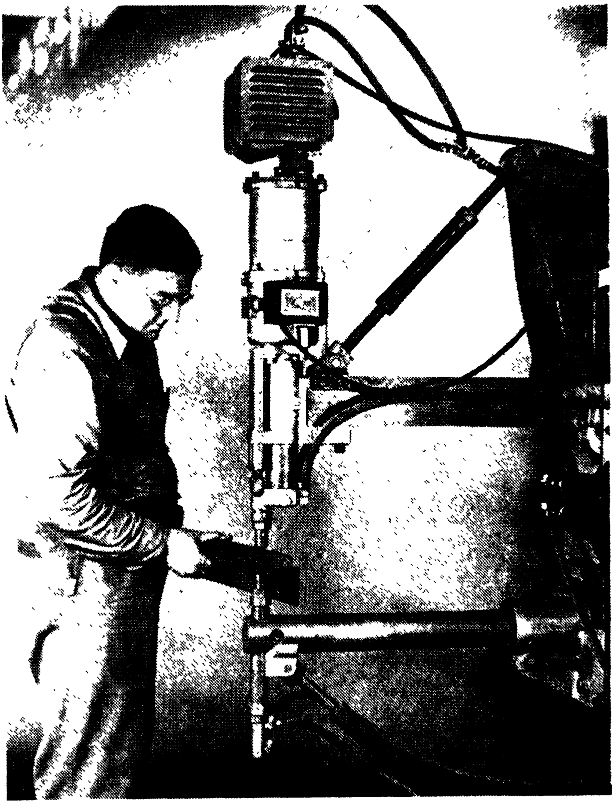


Figure 105. An electrical resistance type forge welder
(Courtesy of: Progressive Welder Company)

Manually operated machines depend to a great extent on the operator for the control of the variables stated above. The size of the electrode contact-areas is of considerable importance, and tables are provided by the manufacturer giving electrode sizes, currents, time, and pressures recommended for varying thicknesses of metal. Special problems such as welding two pieces of different thickness

together, or welding sheet steel to solid rod, etc., require considerable ingenuity on the part of the operator.

To operate a spot welder, one must clean the electrodes, turn on the cooling water, set the variable transformer to the correct current, and turn the power on. Place the metals being spotted on the stationary electrode, and by pressing the foot lever, press the movable electrode against the metal. Pressing the foot pedal a little further will close the switch manipulated by the lever. The spring on the lever and its tension-adjustment control the pressure during welding. When the operator estimates the proper time has elapsed, the current is discontinued by pressing the foot lever to the bottom which opens the lever switch. The operator may now take his time removing the welded article.

111. Resistance Welding Accessories

A resistance, welding-machine operator usually needs gloves, goggles, a file, and pliers to be equipped to use a machine. Because wire electrodes are not used, the raw material consists only of the articles to be welded. If various kinds of articles are to be welded, a number of different shaped tips or electrodes will be found necessary. *Figure 104 and Figure 105.*

112. Review Questions

1. What kind of current is used in a resistance welder?
2. How is the current changed by the transformer?
3. Are resistance welding-machines used for automatic welding?
4. What is the difference between a "Butt welder" and a "Flash welder"?
5. What metals are used for electrodes on resistance welders?
6. Which alloy tends to make the electrode harder?
7. How much current is passed through a spot weld?
8. Why is a "shot" weld given that name?
9. What heats a piece of metal during an "upsetting" operation?
10. Name the four variables of a resistance welding machine.
11. Where is electric resistance welding most commonly used?
12. What is spot welding?
13. Name the principal parts of an electric-resistance welder.
14. Is pressure used in spot welding? Why?

CHAPTER VII

INSPECTING AND TESTING WELDS

One of the most difficult problems in welding is to determine whether the finished weld is up to the expected standard. Appearances are very deceiving at times, and observation cannot be accurate enough to insure that the weld is of sufficient strength. Many methods have been devised whereby the metal can be studied accurately and its full properties revealed. Several of these methods are in use at the present time, no particular method being used as a standard. Tests may include both physical and chemical analysis. These tests may be divided into two main classifications i. e., shop tests and laboratory tests.

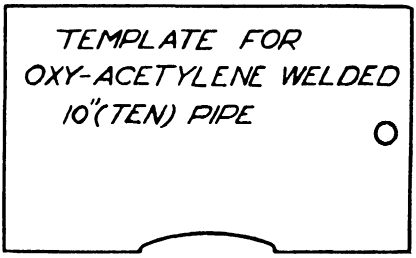


Figure 106. Template for testing welds

113. Shop Methods of Testing Welds

In the welding shop, the welds may be tested by various methods; the care taken with the test will depend upon what the welded material is to be used for. The most rigid tests apply to welded pressure vessels where the weld is to withstand considerable pressure. Repair welding of most equipment may be given a visual inspection. The method of testing welding in shops is divided into three classifications—(1) inspection for appearance, (2) destructive tests, and (3) comparison tests. All of these tests may be classified as physical tests.

114. Inspecting Welds

The inspection of the weld is a popular method of determining the condition of the weld. The inspection includes such items as determining and checking the penetration, the smoothness of the

bead, the amount of added metal, the cleanliness of the finished weld, pits in the weld due to mediocre welding, touch-up spots where the welder has gone over the weld to make it look better, and the even contour of the weld for consistent width, straight line, and even height. Templets are quite often used by the inspector to check welds where uniformity of the seam is important. *Figure 106.*

The inspector must be a person who has had considerable experience in welding and knows the metal which is being welded. At best this type of test is superficial, and cannot under any circumstances determine the condition of the inside of the weld. Considerable trust must be put on the individual welder; repeated tests of an individual welder's work will give an indication of the quality

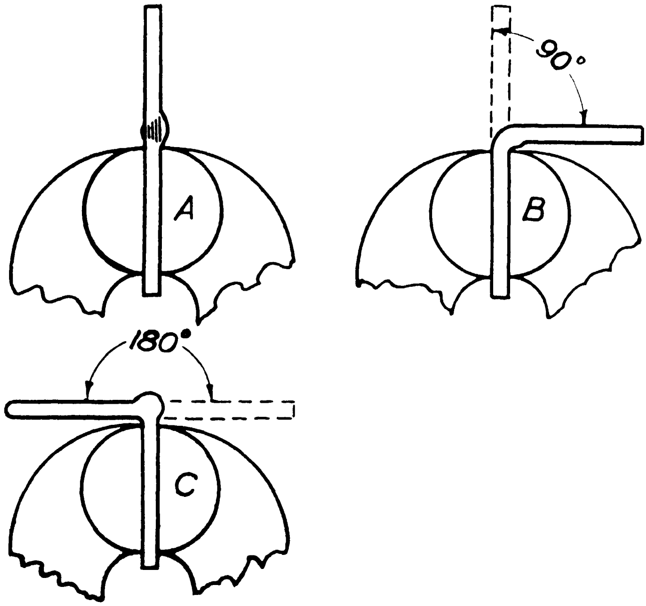


Figure 107. Testing a sample specimen in a vise: A. Before bending, B. After bending 90° (note the weld is closed in on itself to test the penetration), C. After bending back 180°

of welds that may be expected from him. Chapters 1 and 3 include some information as to the inspection of a weld for proper conditions of the preceding items. Pits and touch-up spots are surface conditions which indicate a very poor weld inside; under all conditions this type of weld should be discarded. One popular method of inspection is to reheat the weld using a large tip; any cracks will be indicated by a different color of the metal on each side of the crack.

115. Destructive Tests of Welds

A popular method of testing a weld, which does not require elaborate equipment, is the destructive test. The method is fast and shows most weld faults quite accurately. A sample specimen may be tested to destruction to determine the physical condition of the

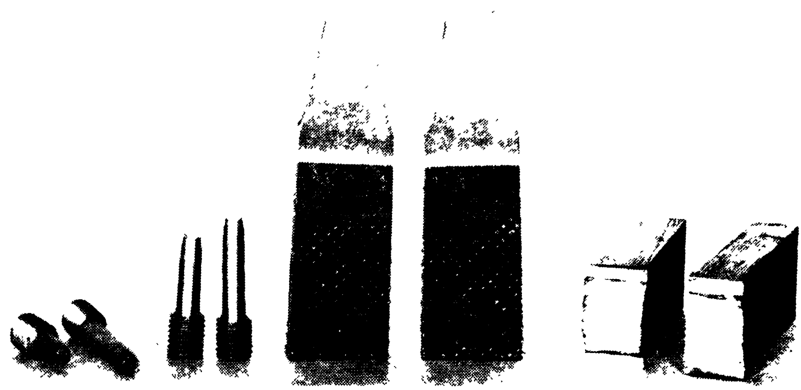


Figure 108. Samples of welds tested to destruction. They are machined all over before tested
(Courtesy of General Electric Company)

weld, and to determine the welder's qualifications. This method is particularly appropriate where large numbers of identical pieces are fabricated. The method of testing is to take one out of every 100 or 1,000 pieces and test it to destruction. The destructive test may show up such qualities as tensile strength, ductility, fusion, penetration, and crystalline structure. The equipment used for a test of this kind depends upon the shape and type of articles to be tested; a common method is to clamp the piece to be tested in a vise and by means of a large bending bar bend the metal at the welded joint. *Figure 107.* This method of bending quickly gives the approximate strength of the weld, while the stretching of the metal determines to some extent its ductility; any cracking of the metal will show false fusion or defective penetration. Many fixtures have been devised to help test weld specimens to destruction. After the weld has been broken, the appearance of the fracture will show the crystalline structure; large crystals usually indicate wrong welding procedure, or heat treatment after welding, while the small crystals indicate a good weld.

116. Comparison Tests of Welds

The comparison test is very similar to the appearance test of welds, with the exception that one sample product is made up to the standard to which all of the other pieces must come before they are permitted to go into use; the inspector will compare the sample product with the pieces that he is inspecting. The test is again a superficial one, and the items looked for are very similar to those listed under the appearance list. Occasionally the same procedure is used to set up the destructive type of weld test where a good sample is made and tested, and all other welds tested must come up to the standard set by the sample test weld.

117. Laboratory Methods of Testing Welds

To determine exactly the strength of a weld, all of the companies who do welding to any extent have established laboratories for scientifically determining the exact characteristics of the weld. These laboratories are equipped with modern equipment, which determines the complete physical and chemical properties of sample specimens. Occasionally, the testing is performed by the metallurgical department, while in some cases a part of the shop is set aside for this purpose.

Some of the items to be determined in a laboratory are:

1. The tensile strength
2. The ductility
3. The hardness
4. The micro-structure
5. The macro-structure (deep etch)
6. The chemical constituents

The conditions under which the specimens are tested are kept identical, meaning that the specimens are all of a standard size. The length need not be the same, but the cross-sectional area must be the same. Samples should also be taken from identical positions from the large weld which is being tested.

The Society of Automotive Engineers, the American Society of Mechanical Engineers, and the American Society of Testing Materials, have all adopted standards for laboratory tests of metals. These standards involve specifications of various physical qualities to be maintained for different types of welds, and specifications for the various test specimens or samples. *Figure 108.* This is all done in order to have a means of comparing the standards of one company with those of another, and to enable standard testing machines to be built.

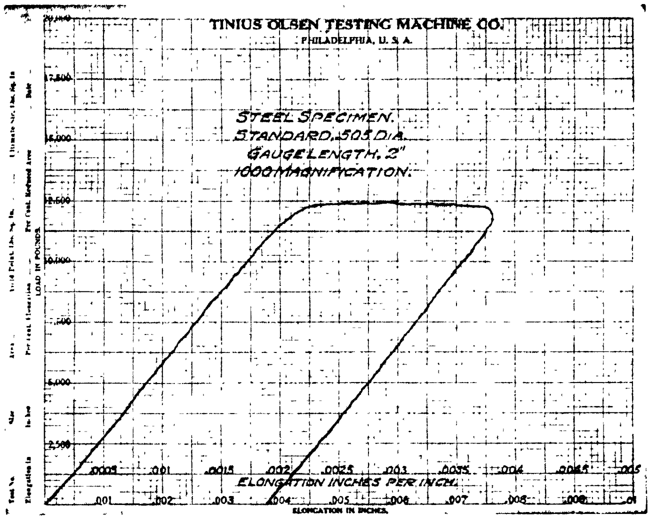


Figure 109. Strength graph of a metal showing the Yield Point and the permanent set left in the steel when returned to new load

(Courtesy of: Tinius Olsen Testing Machine Co.)

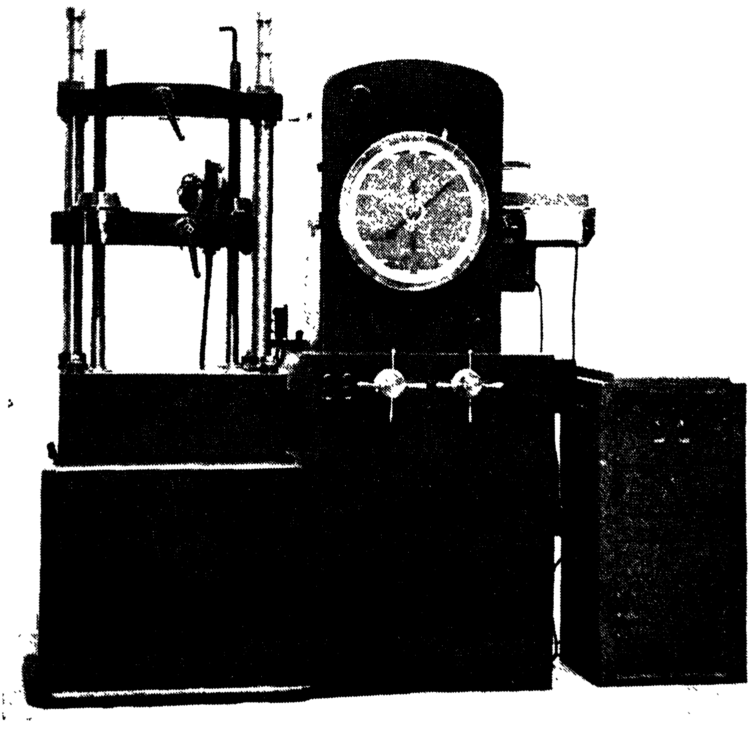


Figure 110. A laboratory type tensile test machine

(Courtesy of: Tinius Olsen Testing Machine Co.)

118. Tensile Ductility Method of Testing Welds

To tensile-test a weld a specimen of the weld is mounted in a machine and stretched. The machine determines three values for the weld; one is the tensile strength of the metal, another is the yield point of the metal, and the third is the ductility of the metal. The tensile strength is recorded as the number of pounds per square inch

Metal	Tensile Strength Welded P. S. I.	Annealed	Heat-Treated Annealed	% of Elongation Annealed
Low Carbon Steel	60,000	55,000	......	30
Medium Carbon Steel	40,000	55,000	55,000	..
Stainless Steel	75,000	95,000	180,000	55
Chrom-Moly Steel	40,000	.....	90,000-180,000	..
Duralumin	20,000	.....	55,000- 65,000	..
High Tensile Steel	75,000	50,000	50,000	25
Hard Surfacing	.....	.....	......	..
Soft 5% Phoylius	.....	.....	85,000	55
Bronze Monel	51,000	51,000	105,000	25
Duralumin 17ST	.....	58,000	......	20

Figure 111. Strength values for various metals

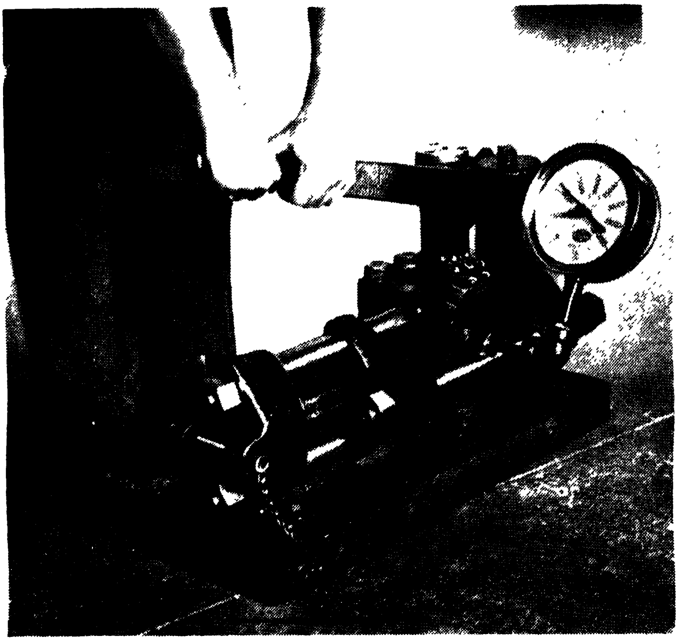


Figure 112. A shop type tensile test bend test machine
(Courtesy of: Air Reduction Sales Company)

required before the metal stretches beyond its elastic limit. The elastic limit of the metal means that it can be stretched just as far, and will return to its original length after the load is released. However, when more load is applied to the specimen after the elastic limit has been reached, the specimen loses its elasticity and the metal will not return to normal. When the specimen stretches instantaneously, or gives at a certain loading, but does not break,

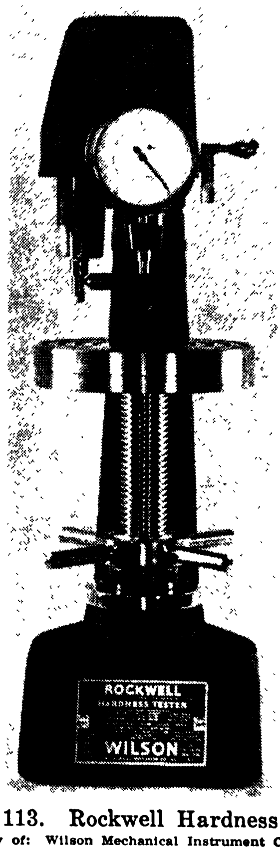


Figure 113. Rockwell Hardness Tester
(Courtesy of: Wilson Mechanical Instrument Co., Inc.)

this is called the yield point. *Figure 109.* The yield point is important inasmuch as it is not desired to load the metal to the point where it will stretch and not return to its former shape. Many machines have been developed to do this testing, and to record directly, and even automatically, the tensile strength of the metal. *Figure 110.* Some of the machines are valued at thousands of dollars while others are made so that they are portable and may be taken around to field locations for testing metals on the premises.

However, they are all Universal and can test metals of different cross-sections and shapes, that is, the machine will test round, oval, square, and rectangular specimens. At the same time that the machine is testing the tensile strength of the metal, it also tests the ductility, meaning the stretchability (elongation) of the metal before it fails. This also is in relation to what is called the elastic limit of the metal. *Figure 111.* To measure the elongation of a

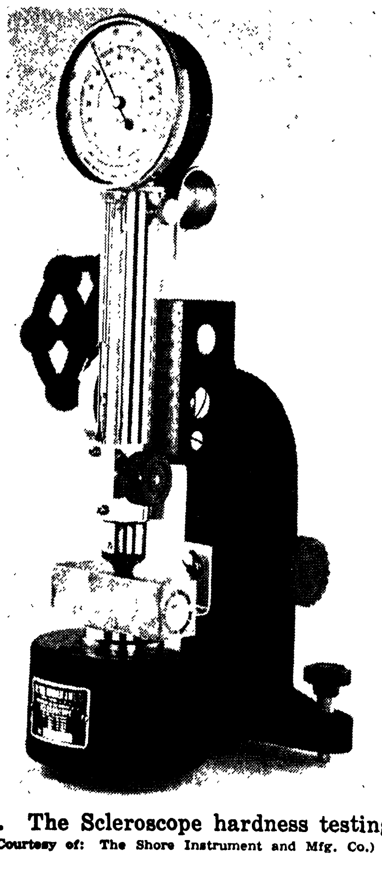


Figure 114. The Scleroscope hardness testing machine
(Courtesy of: The Shore Instrument and Mfg. Co.)

weld, prick-punch two points on the weld specimen, measure the distance between them before, and then measure the distance after the metal has reached its elastic limit. The elongation is determined in per cent by dividing the difference between the two readings by the original distance. Simplified, tensile-test machines using hydraulic pressure have been developed for welding shops. *Figure 112.*

119. Hardness Method of Testing Welds

Another important factor in studying the material is the hardness of the metal. This item is particularly important in regard to welds that must be machined and with special tool metals. There are many special metal alloys used for welding hard surfaces or for welding machine tools. Many machine parts and other surfaces may be welded, and the hardness of the finished weld is very im-

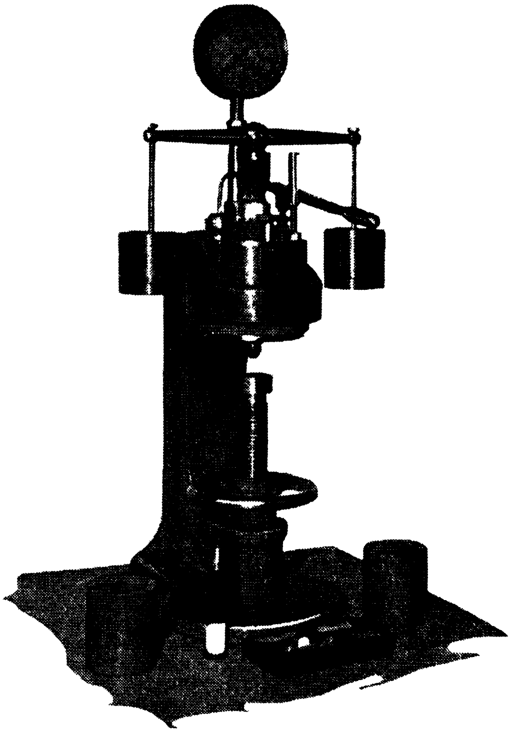


Figure 115. Brinnell Hardness Machine
(Courtesy of: Detroit Testing Machine Co.)

portant in regard to the machinability of the welded metal. The methods of determining the hardness of the metal have been standardized. One of the most popular methods is to use what is called a Rockwell hardness-testing machine. *Figure 113*. This machine works somewhat like a press, being provided with a platform for holding the specimen. A point (which may be either a $\frac{1}{16}''$ diameter ball or a diamond cone ground at a 120° angle) is pressed into the metal under the test by means of fixed weights operating on a leverage. With the ball point, the distance the point penetrates the

metal between the first load (10 kilograms or 22 pounds) and the final or major load (100 kilograms or 220.5 pounds) indicates the hardness on a dial registering from 0-100. The hardness is listed on a scale "B". When using the diamond cone penetrator, the

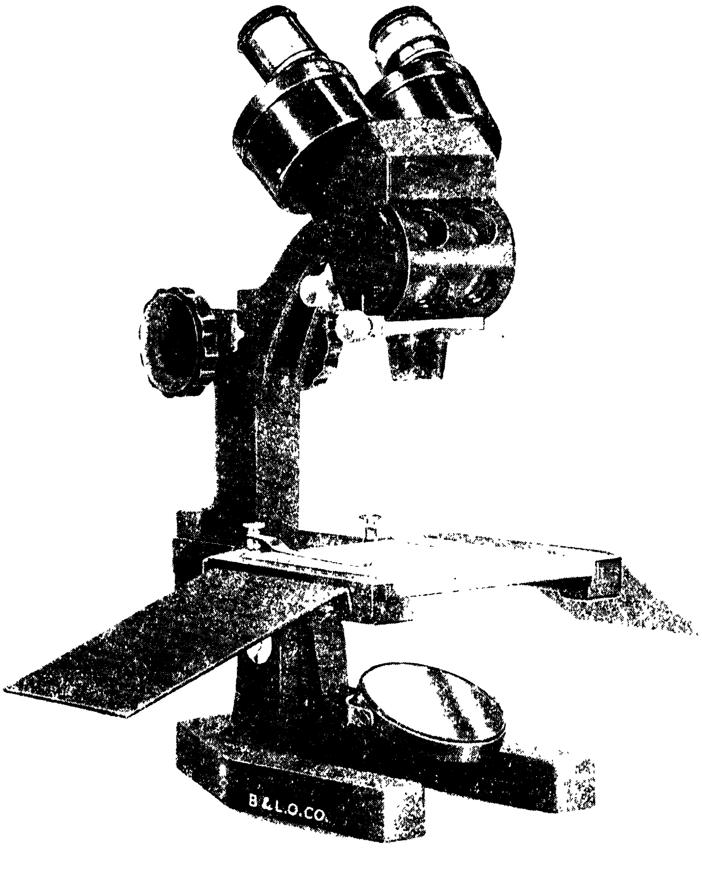


Figure 116. A microscope for 55 to 100 magnification
(Courtesy of: Bausch and Lomb Optical Company)

weights of 10 kilograms or 22 pounds and 150 kilograms or 330.7 pounds are used; the hardness is read on scale "C".

Another method of testing hardness is to use a Shore, direct reading, Scleroscope. This machine is based upon the impact or

rebound of a ball or hammer from a test specimen. The machine consists of a vertical glass tube channel of a certain height; at the top of this is mounted a steel hammer, having a diamond tip of a certain diameter and size. The specimen to be tested is placed below the channel, and the hammer is released. *Figure 114.* The distance that the hammer rebounds after it contacts the metal may be read on the scale beside the channel. The hardness of the metal, as indicated by the scale number with this tester, will range from 0 to 140. The higher the number, the harder the metal. A high carbon steel will indicate approximately 95 points on the scale. A

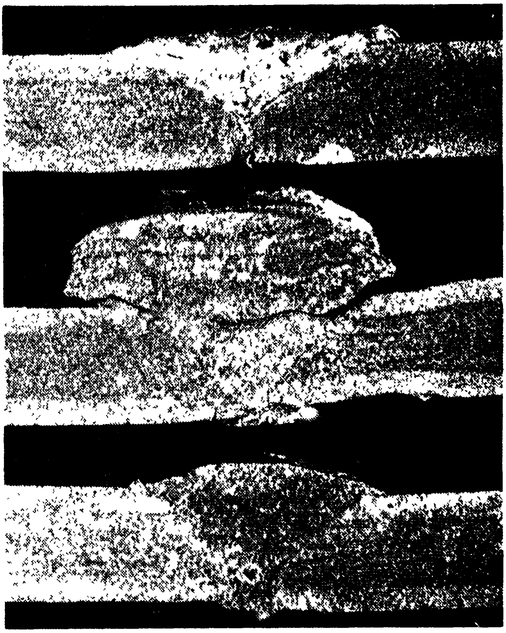


Figure 117. A macroscopic picture of an etched weld cross-section: A (top). Carbonized, B. Oxidized weld, C. Neutral flame weld

rubber tube-and-bulb arrangement manipulates the hammer for testing purposes.

A third method of testing for hardness is to use a machine having a ball point built into an elaborate press (Brinnell Machine). *Figure 115.* The ball point is moved by hydraulic pressure (indicated on a dial scale). The dial indicates the number of pounds pressure exerted on the specimen. The specimen is mounted below the ball, and the ball (10 m.m. dia.) is pressed into the specimen under a load of 3,000 kilograms (6,614 pounds) for 10 seconds. A microscope is used to measure the diameter of the indentation in millimeters. The area of the depression divided by the load gives

the Brinnell-hardness number. A table is always supplied with the machine to permit one to determine the hardness number, once the diameter of the indentation is known. This method is used for testing the softer metals.

120. Microscopic Method of Testing Welds

A test commonly used in the metallurgical laboratory for testing a weld is to procure a sample of the weld and to polish it to a very

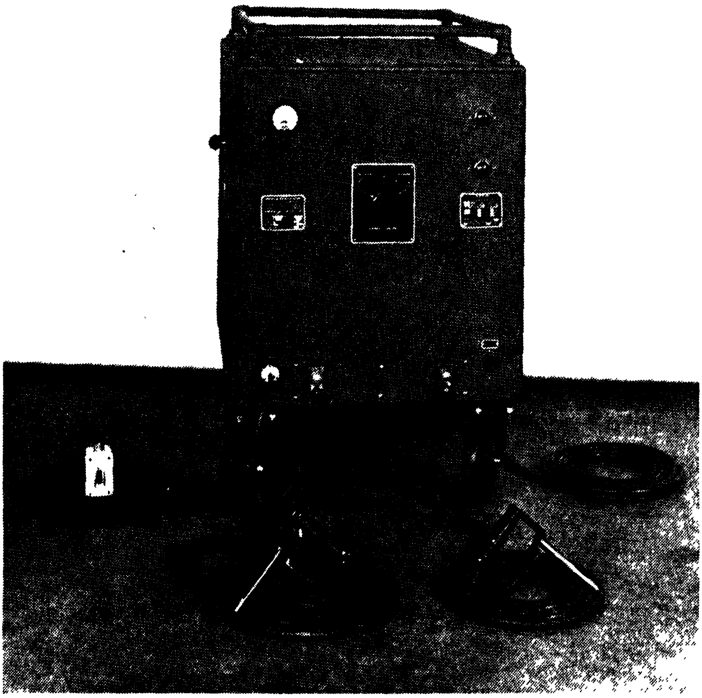


Figure 118. Electro-magnetic tester for welds (Magnaflux)
(Courtesy of: Magnaflux Corporation)

high polish, showing absolutely no scratches on the surface. The sample is then placed underneath a microscope which magnifies the surface of the metal from 50-5000 diameters (usually 100 or 500 diameters). The appearance of the crystals, and the appearance of the metal in general under the microscope, reveals things, such as the amount of impurities in the metal, the heat treatment, etc. In certain standard metals, a microscopic study of the sur-

face can very accurately determine the carbon content and the presence of impurities. *Figure 116.* Occasionally, the metal being worked on is treated with acid or etched. To etch a sample after it has been polished, immerse it in a weak acid solution (10% nitric acid, 90% alcohol, called nitrol, used for steel) for a certain length of time. The metal is studied. Certain acids bring out certain features, such as the kind of impurities, slag spots, poor fusion, etc. A type of weld frequently given this test is the sample that is removed from boiler seams. The most important feature of the micrographic study of the metal is that photographs may be taken

Figure 119. A fillet weld showing a line of filings clinging to the "Magnetic leakage." The crack is approximately ⅛" below the surface in this case

of the metal, and magnified under these conditions; by taking photographs of each specimen, a very accurate comparison may be made between the samples. See Chapter 16 for micro-photographs of the more common metals.

121. Macroscopic Method of Testing Welds

A microscopic view of a weld does not cover enough area to enable one to obtain a picture of an entire weld for inspection purposes. Macroscopic pictures are only 10 magnifications; when the sample is deeply etched with hot nitric acid, the structure of the weld stands out much more clearly. *Figure 117.* The crystalline structure of the metal is not so clearly revealed, but cracks, pits,

and pin holes are much more clearly shown. Scale inclusions are also easily detected by this method. This test also shows up grain (crystal) size. A large grain size indicates improper heat treatment after or during welding.

122. Chemical Analysis Method of Testing Welds

The final complete investigation of the welded material consists of a thorough chemical analysis. The chemical analysis may be both qualitative and quantitative. Qualitative analysis determines the different kinds of chemicals in the metal while the quantitative analysis determines the kind and amount of each chemical in the metal. This type of investigation is necessarily tedious and expensive. The tests are not of direct value to a welder or to a welding company. It is only in cases of having trouble with large quantities of metal that these tests are resorted to. The weldability of a metal is dependent to a great extent on the impurities of the metal, the common impurities being phosphorus, sulphur, and silicon.

123. Magnetic Flux Tests of Welds

A popular method of testing welds, especially pressure vessel welds, is to magnetize the metal temporarily, and then place iron filings on the weld. Any surface cracks, no matter how small, will be revealed by the filings forming in a definite pattern around the crack. This test may be carried out by clamping an electro-magnet to the weld to be tested with its two poles resting on the metal on opposite sides of the weld. *Figure 118.* The complete assembly may be tested by placing the vessel inside a coil of electrified wire (D.C.). This test can sometimes be easily accomplished by winding the cables from a D.C. arc welder around the part to be tested, and adjusting the machine to send a heavy current through the cable. This will produce a strong magnetic field through the weld which, if sprinkled with iron filings, will indicate any flaws in the weld. *Figure 119.*

124. Lime Coating Tests of Welds

Another test for pressure vessels is to coat the surface with a lime solution. After the lime has dried, a pressure is built up in the vessel, and where the lime flakes from the metal, a flaw is indicated as being present. Hydraulic pressure, using water as the fluid, is the usual medium used in this test. This test may also be used to reveal the weakest portion of a welded vessel if enough pressure is created without destroying the vessel.

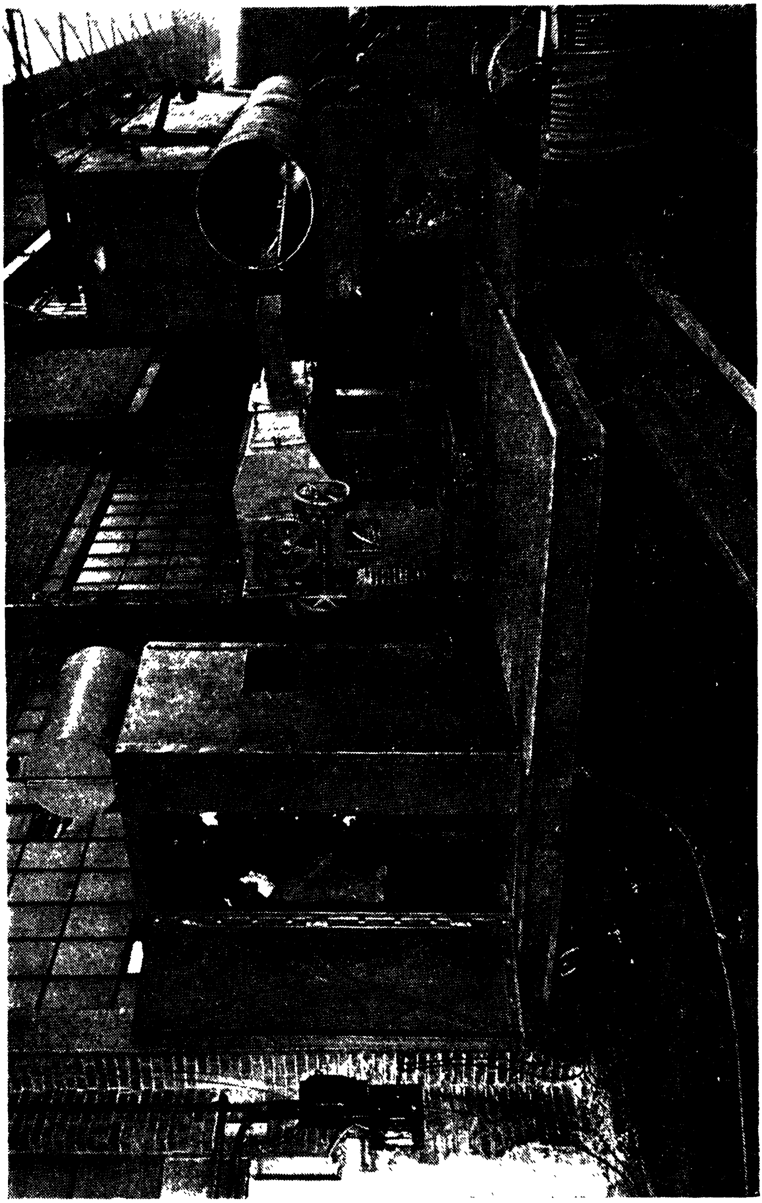


Figure 120. X-Ray test machine: A 400,000 volt machine checking a seam in a pressure vessel
(Courtesy of: General Electric X-Ray Company)

125. Testing Welds by X-Ray

A very good, but rather expensive, non-destructive method of testing welds is by means of the X-Ray. X-Ray photographs may be taken through the weld; any flaws either internal or external will show up in the X-Ray picture. This method was used for testing all the arc welds which were made in the water flues built into the Boulder Dam. *Figure 120.*

126. Air Pressure Tests of Welds

A common method of testing pressure-vessel welds (tanks and pipe lines) to determine if leaks are present is to use a gas or air pressure. Carbon-dioxide gas pressure is the best because of its non-explosive properties when in contact with oils or greases. A small pressure should be built up in the vessel or pipe (25 to 100 pounds per sq. in.), and a soap and water solution put on the out-

Figure 120A. Radiograph of a weld in 1½" plate. It shows a crack at the left and also inclusions in the weld
(Courtesy of: General Electric X-Ray Company)

side of each weld. Leaks will be indicated by the formation of bubbles. After 24 hours, any drop in pressure will also indicate a leak. This test is easily applied. The apparatus is transferable and the test is safe. It is used extensively for oil and gas-pipe-line testing.

127. Stethoscope Tests of Welds

The sound of the metal changes if any flaws such as cracks or blows are present in the otherwise homogeneous mass of a metal (cracked bell, etc.). This occurrence is used by testers to determine the quality of welds. A professional type stethoscope and a light hammer is all the equipment needed. If the pitch or tone changes as one progresses along a weld tapping lightly on one side and touching the stethoscope diaphragm to the other side a flaw is indicated. This test requires continuous concentration of the tester to enable a good continuous check.

128. Review Questions

1. Why is testing of welds considered important?
2. What two general methods are used for testing welds?
3. Why is the destructive test popular in shops?
4. What various societies have standardized methods of testing welds?
5. Why are the appearance tests considered the least accurate?
6. Why are shop destructive tests only comparable ones?
7. What is meant by the elastic limit of a metal?
8. What is meant by the tensile strength of a metal?
9. Name three machines used for testing the hardness of metals?
10. Why is the hardness of machine steel considered important?
11. Do these tests of welds apply to both arc and acetylene welds?
12. Do these tests apply to non-ferrous metals as well as ferrous metals?
13. What is meant by the micro-structure of a weld?
14. Are large crystals detrimental to the strength of a weld?
15. Name some special cases which involve special testing of welds?
16. How many times is pressure applied on the sample when using the Brinnell Hardness Tester?
17. What advantage does X-ray tests have over magnetic flux-tests?
18. What is the usual magnification when viewing a weld through a microscope?
19. Is the ability to bend without breaking considered a good test for welds in mild steel? Why?
20. Is the templet method of inspecting welds usable on pipe welds?

CHAPTER VIII

SOLDERING AND BRAZING

Previous to this chapter, the material in the text pertained to joining two identical pieces of metal together with metal similar to the parent metal. This type of welding results in a homogeneous mass where the welded joint is similar in material and characteristics to the original material. Soldering is a term applied to fastening two like metals or unlike metals together with another metal entirely different from one or both of the parent metals. Another definition is that soldering adheres two metals together without melting either one of them. The theory of soldering is that, using clean surfaces, the binding or joining metal, upon becoming molten, adheres to the parent metal by means of molecular attraction. The molecules of a solder entertwining with the parent metal molecules form a very strong bond.

129. Types of Soldering

From the general definition stated above, it may be seen that there are many different types of soldering. Of these, the most common are the following three: using (1) lead and tin alloy solder, (2) copper and zinc alloy solder, and (3) silver and copper alloy solder. The most common of the above is the lead and tin solder which is given the general term of *soft soldering*, whereas copper soldering and silver soldering together are given the general name of *hard soldering* or brazing.

Copper soldering sometimes uses a copper and tin mixture as the joining metal, in which case the name should be bronze soldering. The solder for brass and bronze soldering is sometimes given the term spelter, while the operation itself, or the actual soldering, is quite commonly called brazing, and it will be named by this term thru the remainder of the text.

130. Soft Soldering

Soft soldering is used where a leak-proof joint, neatness, and sanitation are desired. The joint produced by means of soft soldering is not mechanically very strong, and in many cases a mechanical joint is used in conjunction with the soft solder seam. The soft

solder itself always has lead and tin in the alloy and sometimes another metal, Bismuth. The proportions of the three metals in the final alloy are various, producing entirely different solder properties. Different solders are used for different purposes such as for soldering tin, copper, brass, bronze, sheet iron, and sheet steel. The three most common soft solder alloys are:

1. The medium grade consisting of 50% tin and 50% lead, called 50-50 solder
2. A solder with a lower melting temperature is composed of 33% tin and 67% lead.
3. A maximum strength solder made of 67% tin and 33% lead.

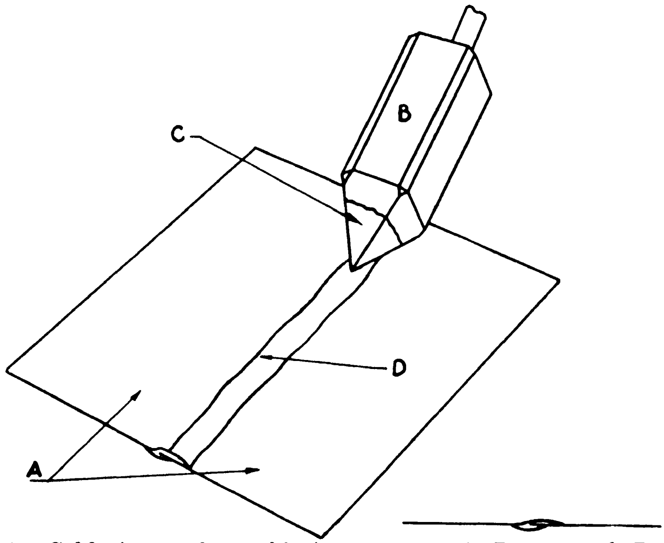


Figure 121. Soldering with a soldering copper: A. Base metal, B. Soldering copper, C. Tinning on soldering copper, D. Soldered seam

The melting temperature of the 50-50 solder is 227° centigrade, or *440° F.* The melting temperature of the 33-67 solder is 188° centigrade or *370° F.* The adding of Bismuth to the above metals produces a much lower-temperature solder. For example, a solder containing 25% tin, 25% lead, and 50% Bismuth will melt at 96.1° centigrade or *205° F.*

131. Methods of Soft Soldering

The three general methods of soft soldering may be performed using a soldering copper, a torch, or a dip bath. Before describing each process in detail, it should be pointed out that several fundamental things must be done in order to produce successful soft soldering. These are.

1. The metals to be soldered together must be chemically clean, and all oxides, grease, and dirt removed.
2. The metals to be soldered together must be heated.
3. The proper flux must be used.
4. The solder itself should be melted only by the metals to be soldered together.
5. An excess of solder is useless and unsightly.

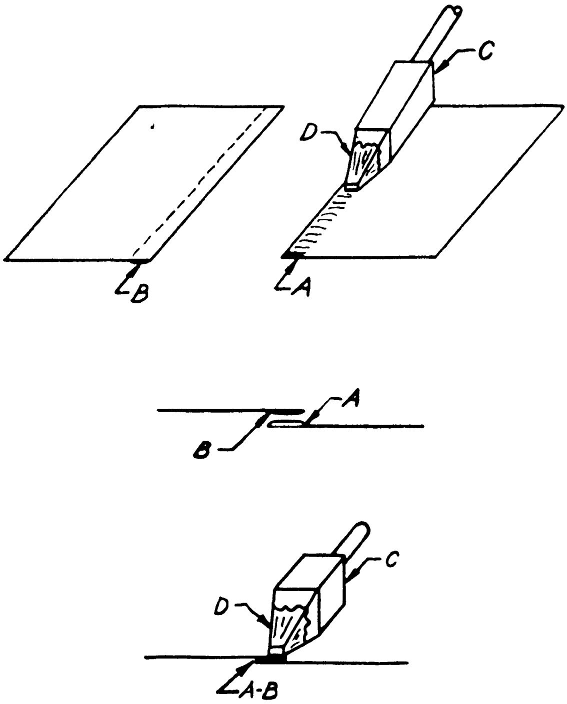


Figure 122. A "sweat" soldered joint: A. Solder applied in a thin film (tinning) with copper (on top), B. Tinned underneath, C. Soldering copper applied (no solder used), D. The tinning on the copper

132. Use of the Soldering Copper

The soldering-copper method of soldering is the oldest and still the most popular method for doing certain types of soft soldering. The soldering copper consists of a square or octagonal solid copper bar with a four sided tapered point. An iron rod is used to fasten the copper head to a wooden handle. *Figure 121.* The purpose of the copper is to act as a source of heat for the soldering. The copper metal itself has a low specific heat, but the efficiency of transmission of the heat through the copper to the work makes this metal very good for soldering purposes. Also copper is very easily tinned, or

coated with solder, so that the molten solder will adhere to it, making the handling of the solder less difficult. The copper may be heated by a gas flame, by a blow torch, or by electricity.

The advantages of soldering copper are that it produces a very concentrated heat, and the copper is not likely to be heated to such a high temperature, that its heat will ruin the articles to be soldered together. It also acts as a means of spreading, or smoothing, the solder at the same time that it is melting and adhering to the metals. It has the disadvantage of requiring reheating quite frequently; the

Figure 123. Jewelers soldering torch. The gas inlet is in the upper center opening, the jeweler blows air through the right end opening; this produces a quickly varied flame at the tip on the left
(Courtesy of: William Dixon, Inc.)

tip of the soldering copper must also be cleaned occasionally. The process of cleaning the soldering copper is called *"tinning."* To *"tin"* a soldering copper, it is necessary to file the point to a smooth coppery finish without leaving any dirt or pits, and then to clean the point chemically by dipping it in a cleaning compound, or to apply the solder to the tip in the presence of sal ammoniac.

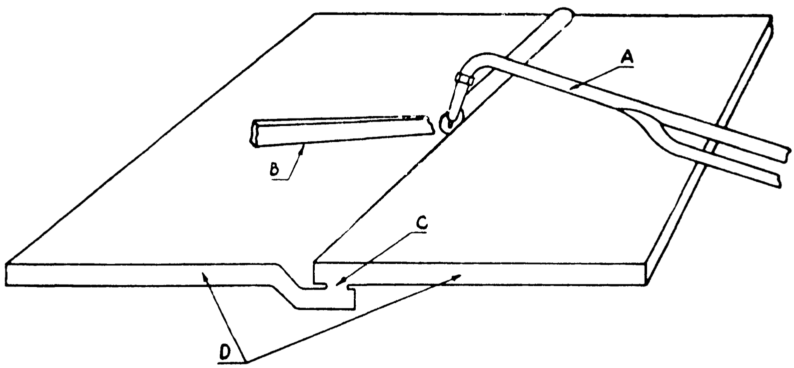


Figure 124. Torch soldering; City gas-oxy.: A. Torch, B. Solder, C. Spot welded point, D. Base metal

One of the best applications of the soldering copper is to use it for "sweating" a soldering joint. By this term is meant that the two metals to be soldered together are lapped at their joint with a film of solder between the two surfaces. The two edges to be lapped together are previously tinned by means of the soldering copper;

the edges are then lapped together, and the copper is slowly pressed along the seam, permitting the heat from the soldering copper to penetrate through the tin to the solder. *Figure 122.* The resultant joint is quite strong and is very neat. Needless to say, the two metals to be soldered together must be carefully cleaned by means of sandpaper or a file, and a flux must be applied to the surface prior to the attempt to solder them.

133. Use of the Soldering Torch (Torch Soldering)

Soldering torches provide a fast and flexible method of soldering. Common soldering torches may be:

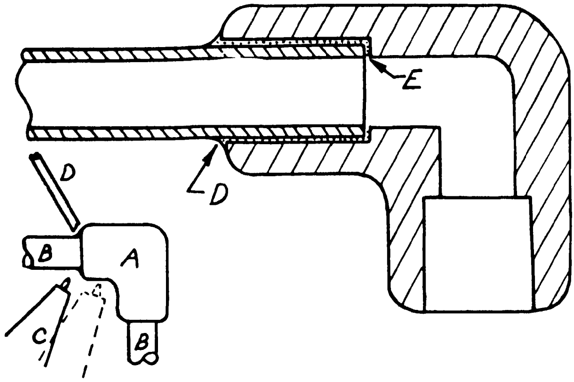


Figure 125. A "capillary" soldered joint: A. Fitting, B. Tubing, C. Torch, D. Solder, E. Tubing stop

1. Gasoline blow torch
2. City gas-oxygen torch
3. City gas-compressed air torch
4. Oxy-acetylene torch.

For small work, the jeweler's city gas torch is often used. *Figure 123.* In order to solder satisfactorily with a torch, the flame must heat the metals to be soldered; it must be absolutely clean so that the surfaces heated will not be corroded in any way by the flame gases; its heat must be concentrated; and it must be easily adjusted. The general method of torch soldering is as follows: Clean the surface with sandpaper, warm this surface with the torch, apply a small quantity of solder at the same time drawing the torch away from the metal (the metal only should melt the solder), and then smooth the surface. Do not hold the torch too close, but keep the inner cone from ½″ to 3″ away from the metal. A very common, torch-soldering fault is to use too much solder, which does not strengthen the joint and is very wasteful. A very

neat looking joint may be obtained by wiping off the excess molten solder, using a clean cloth. The torch method is extremely popular for soldering electrical joints, copper tubing, jewelry, plumbing, refrigeration, and air-conditioning equipment. *Figure 124.*

Another growing use for torch soldering is to build up irregular surfaces on manufactured articles by applying solder in order to secure a smooth finish on the finished article. This method is used extensively in automotive-body manufacturing and in body repair work. The irregular surface is cleaned by first sanding and then washing with a weak acid. A wood paddle is then used to apply the solder to the torch-heated surfaces. The solder is then "dressed" by filing and sanding.

134. The Dip Bath Method of Soldering

This is a production method of soldering used for small articles. It consists of melting a large quantity of solder in a tank and protecting the solder by means of a hood or some chemical covering, such as powdered charcoal, to prevent oxidation. The articles to be soldered are dipped in an acid bath and are then dipped in the solder bath. The method is a labor-saving device to solder coat the surfaces to make them rust proof and also to fasten the various parts together. The articles to be soldered together are assembled and are then acid cleaned, "pickled," after which they are thoroughly washed and dried before being dipped into the solder bath. The article is then lifted out of the bath; the excess solder is allowed to drain from the surfaces, leaving a bright, tinned appearance. One very important precaution to be observed with this method is that under no circumstances should any articles which have the slightest amount of moisture be put into the bath. A small amount of moisture will produce high-temperature steam, causing an explosion of the bath with possible injuries to the workmen and destruction to property.

135. Special Applications of Soft Soldering

Many special applications have been devised for soft soldering, most of which come under the "sweat joint" type of construction. A sweated joint is obtained by coating two surfaces with solder, bringing these two surfaces together, and then heating them until the solder melts and fusion takes place. Another class of special applications comes under the heading of "Capillary action" joints. This type utilizes the principle that when two surfaces are placed close together, a liquid placed in any one spot between them will

quickly spread to all parts of the space between the two surfaces. An example of this latter method is the new method of installing copper and brass pipe. Instead of threading the joints, a special fitting is made, into which the pipe is inserted. The joint has .001″ to .002″ clearance.

Upon heating these pieces and applying solder to the joint, the solder instantly fills in this space by capillary attraction, and makes an exceedingly strong and neat joint. *Figure 125.*

136. Soft Solder Flux

Much has been made of the fact that the joints to be soldered must be chemically clean because the presence of the least bit of dirt, or of the slightest amount of oxidized surfaces, will prevent good soldering. The chemicals to be used depends upon the kind of metals to be soldered together. When soldering copper and iron, salammoniac (ammonium chloride) is an effective flux. Sheet metals, copper, brass, etc., are best soldered when a zinc chloride flux is used, while hydrochloric acid (muriatic acid), with an excess of zinc is best for galvanized iron. Articles coated with tin and other soft alloys can best be soldered when a rosin-dissolved-in-alcohol flux is used. Cast-iron flux usually consists of zinc chloride added to tallow and heated to a brown color. A solution of zinc chloride may be used for the same purpose.

137. Hard Soldering (Copper and Zinc Soldering)

Hard soldering uses alloys which melt at a much higher temperature than soft soldering alloys, and they produce a much stronger joint. They are used where mechanical strength is desired in addition to a leak-proof joint. The method of fastening some metals together by means of a hard solder is also used where welding them would be impracticable, because of the fact that their melting, or fusion, point is different. Examples: steel tubing welded to cast iron, copper tubing welded to steel, and tool steel to low carbon steel. By hard soldering, or brazing, heat-treated metals, the heat treatment is usually retained. The most common hard solders are brass and bronze. Brass is composed of various compounds of copper and zinc, whereas bronze consists of different alloys of copper and tin.

The most common proportion of copper and zinc in brass is 80% copper and 20% zinc, and this alloy melts at 1,700° F. Other combinations sometimes used are: 70% copper and 30% zinc; 60% copper and 40% zinc; and 50% copper and 50% zinc. These latter alloys melt at temperatures up to 1,850° F. Occasionally the brass

alloy has included in it some third metal. The procedure of hard soldering, using brass, is very similar to soft soldering, with the exception that higher temperatures are needed to procure good fusion.

Some common pointers to be followed in order to secure a good braze are as follows.

1. The metals to be joined must be chemically clean.
2. The metals to be joined must be heated to a temperature above the melting temperature of the brass, but below their own critical or melting temperature. In case of steel, the metal is heated to a dull cherry red.
3. To reduce oxidation and to float the oxides to the surface, a pure, fresh flux must be applied as the brazing proceeds. Borax makes a good brazing flux.
4. A forced air city gas flame or a hotter flame is usually required in order to obtain a high enough temperature to secure a good joint.
5. The torch flame (oxy-acetylene) is usually used as a neutral flame. However, a carbonizing flame will produce an exceptionally neat looking joint, but strength will be sacrificed. A neutral flame will give the best results under ordinary conditions, whereas an oxidizing flame will produce a rough looking braze; but tests have proved that a braze made with a slightly oxidizing flame is the strongest of the three.
6. Just as in steel welding, penetration must be secured in the brazed joint. This penetration must be such that the braze seeps through the joint and adheres to the two surfaces. A minimum amount of brazing material should be used.
7. The two pieces to be brazed together must fit tightly. That is, the metals should not be spaced any appreciable distance apart.
8. The braze must be cooled slowly to secure the maximum strength of the original metal. The rate of cooling does not affect the braze.

138. Hard Soldering with Brass

Prepare the pieces to be hard soldered just as they are prepared for steel welding. That is, provision for contraction and expansion must be made and if the metal is thicker than eight-gauge it must be grooved or chamfered to permit adequate penetration. In addition, the surfaces to which the braze is to adhere must be cleaned by means of a file or sand paper, an emery wheel is not recommended due to the danger of embedding abrasive particles). Ad-

just the torch for whatever flame is desired using the same size tip as would be used for welding the same thickness of metal. Using the torch as the heating medium, warm the first two or three inches of the brass filler rod, and then dip the heated end into the flux container. This will coat the filler rod with semi-fused flux an eighth to a quarter inch in thickness. Now apply the torch to the metals to be brazed, heating the metals (each one equally) to a dull cherry red. The width of the braze seam will be determined by how wide a portion of the metal is heated to a cherry red. The brass will not flow over the surface unless it is red hot. The width of the braze should be a little wider than a steel weld on the same

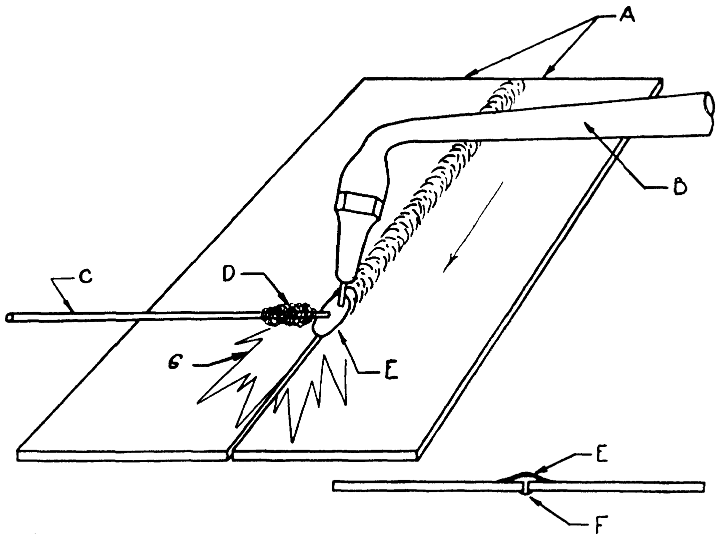


Figure 126. Brazing a steel joint (flat butt) 1/16": A. Base metal, B. Torch, C. Brass filler rod, D. Flux, E. Puddle & Bead, F. Penetration, G. The liquefied flux spreading on the steel surface ahead of the weld

thickness of metal. While heating the metal, the brazing rod should be kept near the torch flame in order to maintain a fairly high rod temperature. *Figure 126.* After the metal has been heated, bring the filler rod (fluxed coated portion) into contact with the cherry red metal, maintaining the torch motion. The filler rod will quickly melt and flow over the parent metal. Do not overheat the filler rod, keep it away from the inner core. The weld should then proceed along the joint just as in the welding process with the exception that the procedure will be quicker. The torch flame is not held as close to the metal as in steel welding (approximately double the distance). The finished braze should be permitted to cool slowly (quenching it or placing it on a cold surface will cool the parent

metal too quickly and weaken it). The finished braze should have the appearance of adequate fusion with the parent metal, and the brass should penetrate through the joint and appear underneath evenly. A white deposit on outside of the brass indicates an overheated braze joint, also the color of the brazed joint will indicate if it has been overheated. The best looking joint will show a color exactly similar to the brazing rod used, whereas if the filler rod is heated to an excessive temperature some of the zinc will be burned out leaving a coppery appearance, while if an oxidizing flame is used, the weld will have a red color due to the oxidation of the copper. *Figure 127.*

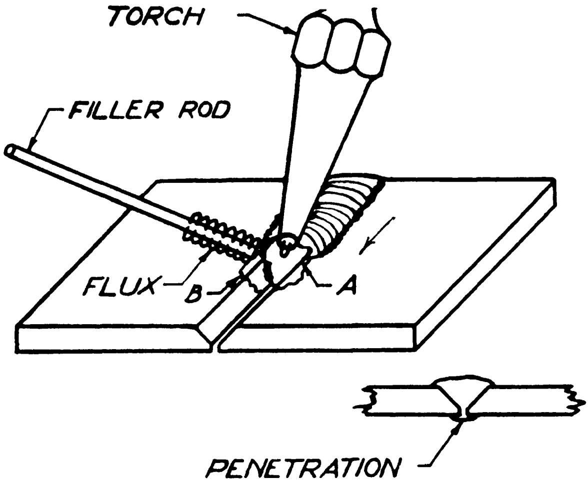


Figure 127. Brazing a steel joint (flat butt) ¼": A. Puddle, B. Liquefied flux

139. Hard Soldering with Bronze

Bronze, as mentioned previously, is an alloy consisting of copper and tin (usually 90% copper and 10% tin, and melts between 1600° F. and 1850° F.). The instructions in the previous paragraph apply to bronze hard soldering as well as brazing. The only differences will be that the bronze filler rod produces a stronger joint due to its greater inherent strength. During the soldering a higher temperature is required to produce sufficient fusion. The same flux is usually used and the appearance test is approximately the same. *Figure 128.* A very common bronze used in hard soldering is called Tobin Bronze, which is a patented alloy of copper and tin. Cast iron may also be bronze welded. A special flux is necessary and it is important to carefully clean the cast iron and use a slightly oxidizing flame. The metal must be heated to a bright red. *Figure 129.*

140. Silver Brazing

Occasionally a soldered joint is required, which must stand up under exceptionally high temperatures, or which must be exceptionally strong and withstand considerable corrosion. In the fabrication of jewelry, small precision articles, and instruments which re-

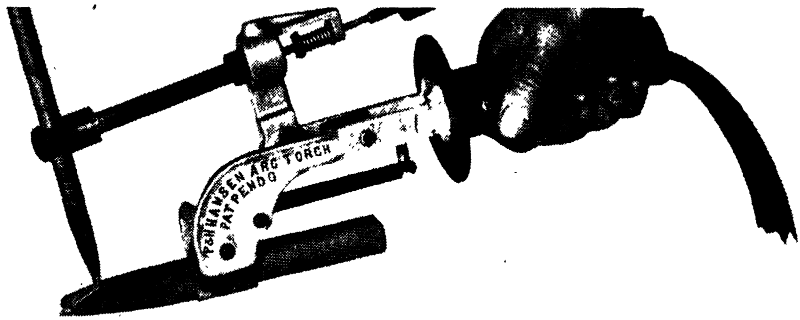


Figure 128. A carbon arc brazing torch
(Courtesy of: Harnischfeger Corporation)

quire the use of strong joints various silver alloys have been developed to be used as solders. The original use of silver alloys was in jewelry manufacturing while at present there are very few industries that do not have use for this method of brazing. Silver brazing is used on an exceptionally large scale. Many alloys of silver have been developed, the different ones having different melting points, strengths, and colors. Silver alloys may be procured that melt at relatively low temperatures and also up to fairly high temperatures, and they may be obtained in the silver colored, copper colored, or gold colored forms. Silver brazing is done by several methods: (1) the sweat method, (2) the city, gas, and blow pipe method, and (3) the welding torch method. The fluxes used for silver brazing must be clean, chemically pure and fresh. Chlorides are popularly used as silver brazing fluxes. A borax made into a paste with water may also be used successfully as a silver braze flux.

Due to the cost of the silver alloy, a brazing job wherein silver solder is used should always be as neat as possible. The application or the method of performing the brazing varies in no way from the hard soldering described above. The metals which form the alloys of silver are gold, silver, copper, cadmium, and zinc. The very best grades of silver solder naturally are the ones which are formed partly of gold. This type of solder is used only in jewelry work and with the very best of precision instrument work. A very good practical silver alloy consists of 45% silver, 14% spring brass, and 4%

copper. Another common silver alloy consists of 15% silver, 80% copper, and 5% phosphorus. See Paragraph *320*.

141. Brazing Cast Iron and Malleable Iron

Cast iron may be brazed quite satisfactorily. The cast iron surface should be processed much the same as for welding except that the surface should not be ground, rather it should be filed or machined. Grinding smears the graphite particles over the grains of iron and

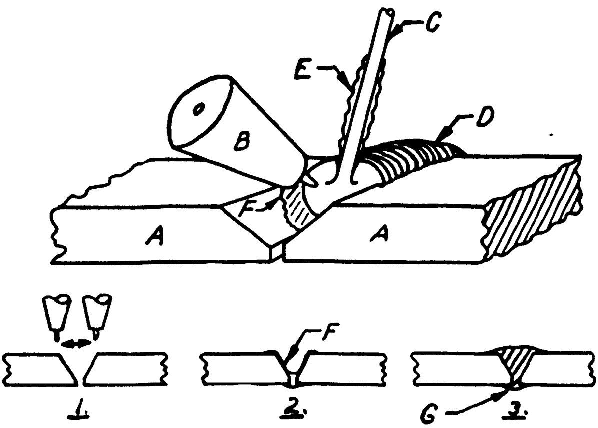


Figure 129. Backward method of brazing cast iron: A. Base metal (cast iron), B. Torch, C. Brass filler rod, D. Finished braze, E. Flux, F. Tinning; *1* Oxidizing torch preheat; *2* Trimming; *3* Finished braze; G. Penetration

makes adhesion between the braze and the iron very weak. The joint may be reinforced the same as for cast iron welding. See *Figure 155*. For best results preheat the casting to a temperature between 400°F and 600°F. Cast iron brazing flux must be used. Brazing rod for cast iron brazing should be a high temperature rod (melting temperature appropriate 1700°F). Such rods are usually high in copper content with some nickel added. Nickel has the property of making the joint metal adhere better to the iron. The high temperature also assists in removing the graphite from the joint. *Figure 129.*

Use a high heat soft flame (large tip, low acetylene-oxygen pressure). A high velocity flame (small tip, high pressure) tends to blow the flux away from the joint, and a poor braze will result.

As indicated in paragraph 173 the welding of malleable iron is not recommended. Brazing is the only satisfactory repair for broken malleable castings. The procedure for brazing malleable castings is the same as for brazing cast iron, except that no preheating is nec-

essary. For both cast iron and malleable iron the brazed joint should be cooled slowly by placing it in a box filled with sand or powdered asbestos.

142. Aluminum Soldering

Also see Paragraph *323*.

One of the most difficult soldering tasks is to solder articles made of aluminum, (i. e. cooking utensils, small manufactured articles, etc.). It is recommended, if possible, to weld any aluminum fractures rather than attempt to solder them. (See Chapter 7). Lead solders cannot be used for soldering aluminum due to the inability of the aluminum and lead to combine. Therefore, special solders must be prepared for aluminum. Some of these are as follows:

1. 60% tin, 37% zinc, and 3% copper
2. 75% tin, 13% zinc, 6% aluminum, and 6% sodium chloride
3. 50% tin, 30% zinc, and 20% lead

The last alloy is not considered as good as the others due to its lead content. To secure the best results, the parts soldered together should be under pressure until the solder cools to room temperature.

143. Review Questions

1. What is soldering?
2. Name the different types of soldering.
3. What sources of heating are used for soldering?
4. What is the purpose of the flux?
5. Why are oxides detrimental to soldering?
6. What alloy is used for soft soldering?
7. What is the indication when the soldering copper is becoming too hot?
8. Name three alloys used in hard soldering.
9. What is the melting temperature of 50-50 soft soldering?
10. May a welding torch be used for soft soldering?
11. Name the constituents of a silver brazing alloy.
12. Why is silver brazing used extensively?
13. What is meant by C. P.?
14. To what temperature must steel be heated when brazing it?
15. What is meant by Tobin Bronze?
16. Name one typical application of soft soldering, brazing, and silver brazing.
17. Why can't aluminum be soldered with 50-50 soft solder?
18. What gives a brazed joint a coppery appearance?

CHAPTER IX

NON-FERROUS WELDING

Non-ferrous metals consist of all metals not composed of iron or steel.

While many metals are placed under the general class of non-ferrous, the most popular of the non-ferrous metals are:

1. Copper and its alloys
2. Aluminum and its alloys
3. Lead and its alloys
4. Zinc and its alloys

144. Oxy-Acetylene Welding Copper

Alloys of copper are used a great deal, mainly because of its ductility, which enables it to be worked very easily and shaped into many complicated patterns. Its alloys are used in both the cast and stamped form. It is resistant to certain kinds of corrosion, and it also is a very good conductor of heat and electricity. Its alloys may be recognized by their characteristic red color.

Pure deoxidized copper is comparatively easy to weld, while some alloys of copper are very difficult to weld. In order to test a specimen to determine if it may be easily welded, quickly heat a sample of the metal with a torch to the molten state. If the puddle remains quiet, clear, and shiny, it indicates that the metal is comparatively pure copper, and that it will be easy to weld. However, if the puddle boils vigorously and gives off a quantity of gaseous fumes, this indicates impurities in the metal and it may be difficult to weld.

Also if the metal sample is brittle and breaks easily, this is an indication of alloying elements or impurities. The alloying elements which make welding copper alloys most difficult are: bismuth, antimony, and arsenic. Phosphorus, in small quantities makes welding copper easier.

Copper and its alloys may be welded with either the oxy-acetylene or the electric arc process, and the general procedure is much the same as that to be followed in welding steel. No flux is needed when welding pure copper. However, in welding copper alloys a flux is needed. The physical properties of copper require certain changes in the welding procedure. Welds on copper in its commer-

cial state, produce poor welds usually because of the cupreous oxide dissolved in it. Mechanically-working, commercial copper after welding will be strengthened. The weakest point of a copper weld is next to the joint. Always use specially prepared filler rods for copper welding in order to obtain deoxidized copper. Old transformer wire that has been in a fire has proved to be an excellent filler rod for copper welding. One difficulty encountered in welding copper is the elimination of blow holes and gas bubbles in the finished weld. This may be partially remedied by the use of small quantities of phosphorous in the filler rod. When welding copper, it must be remembered that because of the rapid conduction of heat a tip larger than normal must be used.

145. Electric Arc Welding Copper

Copper may be welded very successfully using the "long" (high voltage) carbon arc. Set the welding machine on straight polarity and with a voltage of 40 to 60 volts for good results. Copper has the following tensile strength:

Pure copper plate	32,000 lbs. per sq. in.
Deoxidizing copper weld	26,250 lbs. per sq. in.
Oxidizing weld	15,500 lbs. per sq. in.

A copper weld should always be backed by a steel plate during the welding operation.

146. Oxy-Acetylene Welding Brass

Brass consists of an alloy of copper and zinc, the proportion of the two metals being variable (10% to 40% zinc). Occasionally other metals are added to the alloy. These, however, do not affect the welding procedure. The alloy has a much brighter appearance (more yellow) than pure copper. It is a very common alloy and is easily recognized.

The alloy is not so ductile as copper, but it does have a higher tensile strength, and its resistance to certain corrosive action is better than that of pure copper.

Brass is more difficult to weld than copper, because of the fact that some of the zinc under the high temperature that is required to melt the copper in the alloy will vaporize, forming an irritant fume, and at the same time destroying the proportions of the metal in the alloy.

When welding brass, the proportions of the two metals should be known, and the filler rod used should be a similar alloy. If the color of the parent metal and of filler rod is the same this will

usually indicate that the alloys are approximately the same. It is more important to use good flux in welding brass than in welding copper. Fresh, chemically-clean, borax paste may be satisfactorily used for brass welding flux. The torch flame should be slightly oxidizing to reduce the zinc fumes, and to reduce the tendency for gas pockets to form. A carbonizing flame has a tendency to form gas pockets and to permit the weld to accumulate too much width, wasting considerable heat.

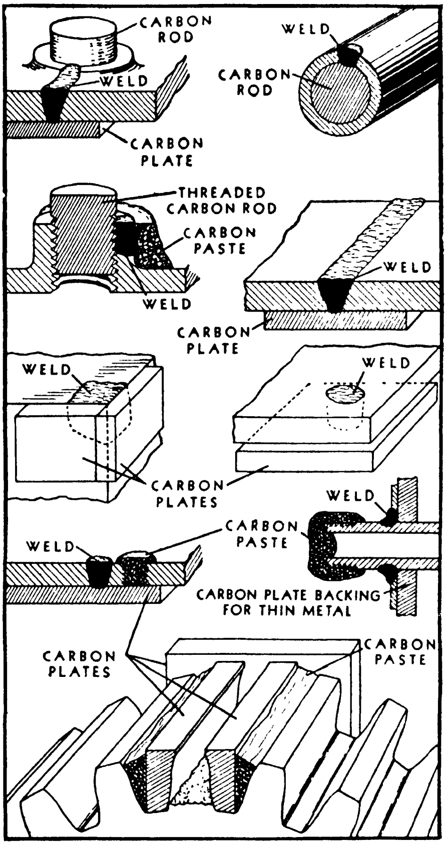


Figure 130. **Carbon block backing in typical application**
(Courtesy of: National Carbon Company, Inc.)

One of the most common applications of brass welding is the use of brass filler rod to fuse two different steels together or to join unlike metals together. This practice in using brass as a joining metal is called hard soldering or brazing. A good flux is necessary when brazing. Chlorides are again the principal ingredients for

brazing fluxes. This hard soldering practice is described in detail in Chapter 8.

Carbon blocks will be found a handy accessory as backing material, especially when there is danger of the weld penetrating too much. *Figure 130.*

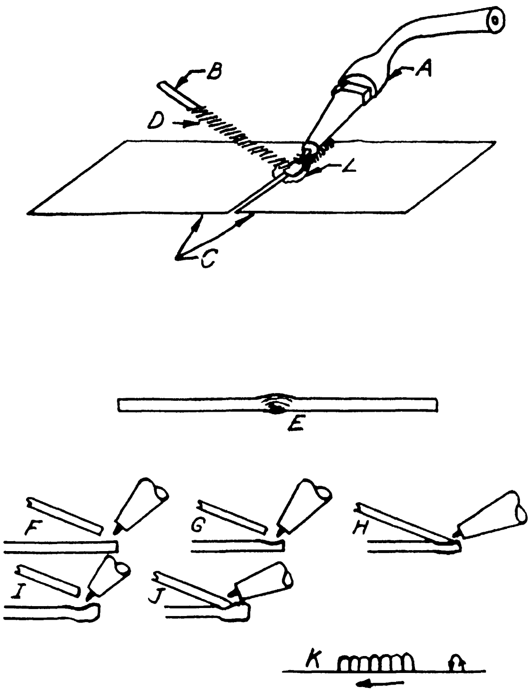


Figure 131. Welding sheet aluminum: A. Torch, B. Filler rod, C. Base metal, D. Flux, E. End view showing build up and penetration, F. Heating metal, G. Base metal melting, H. Dipping filler rod in puddle, I. Lifting filler rod and moving torch forward, J. Dipping filler rod in puddle, K. Filler rod motion, L. Flux spreading on metal

147. Electric Arc Welding Brass

Special electrodes are available for arc welding brass. The metal is prepared in a manner similar to the preparation of the metal for oxy-acetylene welding. Reversed polarity is commonly used and a slightly higher current (10% to 20%) is used than for steel of the same thickness. The welds should be backed with steel or carbon plate and weld rod be preheated. Typical electrode motions are recommended and one should maintain a short arc. Always weld in a flat position if possible. The weld should show a clean, drawn appearance after the slag has been removed by chipping.

The metal may also be welded using a double electrode carbon arc with only reflected heat melting the metal.

148. Oxy-Acetylene Welding Bronze

Bronze is an alloy of copper and tin in various proportions. Some of the bronze alloys may also have a lead content. This alloy is very resistant to corrosion. Its resistance is greater than that of the brass alloys. Also it is easier to weld than the brass alloys, inasmuch as the tin does not have the tendency to separate from the copper in the molten state. An oxidizing flame should be used for this type of welding in order to eliminate fumes as much as possible.

The three metals named above become liquid without appreciably changing their color, and this is one of the main reasons the beginner experiences difficulty when welding them. However, a little practice soon overcomes this difficulty.

The edges to be welded together should be chamfered so that the total angle will be approximately 90°, also backing material is recommended. Filler rods of the same alloys as the parent metal should be used when welding brass or bronze.

149. Arc Welding Bronze

Metallic bronze electrodes, heavily coated, are being used to weld bronze. This process is rather expensive and is not as popular as the oxy-acetylene method. Use reversed polarity with a short arc and back the weld with steel plate or carbon plate. As in brass welding, use a slightly higher current than is used for steel of the same thickness.

150. Oxy-Acetylene Welding Sheet Aluminum

Aluminum is used commercially in two forms, cast aluminum and drawn or rolled sheet. The welding procedure will be governed by the form; cast or drawn. Certain characteristics of aluminum make it rather difficult to weld. These characteristics are:

1. The ease with which the aluminum oxidizes.
2. The melting of the aluminum before it changes color.
3. The oxide melts at a much higher temperature than the metal.
4. The oxide is heavier than the metal (more dense).

However, despite these difficulties aluminum welds can be made which are just as strong and ductile as the original metals. The filler rod should be of aluminum, in the cast form for cast aluminum, and in the wire form for sheet or spun aluminum.

Many containers are made of sheet aluminum, and the seams are welded to insure a leak-proof joint. In welding this type of joint, the welder must obtain the same results as in steel welding. These are: good fusion, penetration, a straight weld, a build-up over the seam, and a clean appearance. When welding, the operator usually mixes the flux with water to form a paste. The edges to be welded together are then heated and the paste applied to both edges with a brush. If the inside of the fabricated part cannot be cleaned, one should not put flux on the metal, only on the filler rod. In any case the filler rod should also be coated with this flux. Due to the high heat conductivity of aluminum, a larger torch tip is needed for a corresponding thickness of aluminum than for steel welding. Be-

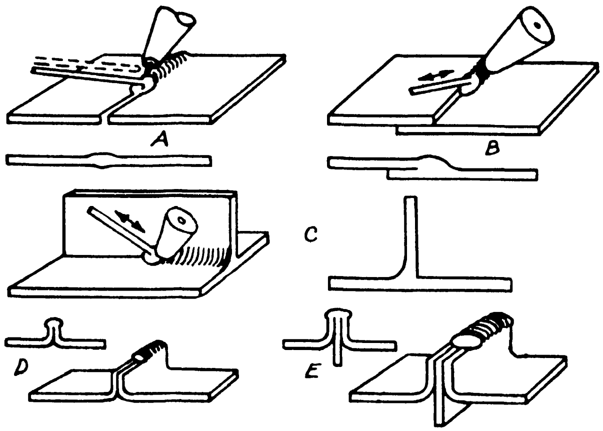


Figure 132. Sheet aluminum welds: A. Butt weld, note the dipping action of the filler rod; B. Lap weld, note the angle of the torch and the filler rod pushing the puddle back, C. Tee weld, D. Two piece deep flange weld, E. Three piece deep flange weld

cause the weld does not spark a large tip may be used and the flame reduced without the torch "popping." The operator cannot very easily tell by the appearance when the parent metal is becoming molten. Light blue glasses should be used, and the welder can then see the light gray color of the metal just as it is melting. He may also "feel" the surface of the metal with the filler rod by lightly touching the metal with filler rod as the metal is heated. The aluminum may be solid one instant, and then without any change in appearance melt and sag. The operator will feel this change coming as the metal surface will feel soft or elastic under the filler rod just as the metal melts. *Figure 131.* The instant that this "feel" indicates that the metal is about to melt the filler rod should not be withdrawn from the metal, but the tip of the filler rod should be

allowed to melt with the metal. If the filler rod is withdrawn at the instant of melting, there is danger (particularly with thin metal) of the metal breaking away and part coming away with the filler rod leaving a hole in the work being welded. However, by a little practice and by learning the knack of scraping the surface with the filler rod, a good steel welder is soon able to obtain a strong neat looking aluminum joint weld.

151. Oxy-Hydrogen Welding Aluminum

Since the oxy-hydrogen flame has a temperature of 4100° F. and because it is very clean, it is used extensively for welding aluminum in the aircraft industry. Inasmuch as it requires only ½ of one cubic foot of oxygen to combine with one cubic foot of hydrogen and because 50% of the oxygen comes from the air, an oxy-hydrogen welding outfit uses 4 cubic feet of hydrogen to one cubic foot of oxygen.

The opening of an oxy-hydrogen station is exactly similar to the steps followed when opening an oxy-acetylene station. The hydrogen cylinder is built similar to an oxygen cylinder except that it is painted black and the regulator attaching nut has left-hand threads. The average cylinder holds 195 cubic feet of hydrogen at 2000 lbs. per sq. inch when full.

The hydrogen torch releases 436 B.t.u. per cubic foot in comparison to the 1,640 B.t.u. released per cu. ft. of acetylene. This necessitates the use of a larger tip orifice than the oxy-acetylene flame requires for a given metal thickness.

To adjust the oxy-hydrogen flame; open the hydrogen torch valve about ½ turn, light the gas, adjust the regulator until the burning gas (almost colorless) just starts to hiss and become turbulent, or rough, then open the oxygen torch valve and adjust the regulator until an inner cone is just visible.

If the end of the tip is dirty or coated with aluminum flux the flame will have an orange color and the inner cone will not be visible. Clean the end of the tip with fine grain polishing paper and ream the orifice very lightly to remove the impurities causing the orange color. The hydrogen flame is almost colorless and the neutral flame is hard to ascertain even under good working conditions. The inner cone will be about ¼ inch long for a No. 4 tip. A black background assists one to see the flame more clearly.

Another way of determining the length of the inner cone is to slowly move the torch up to a cold metal surface. When a small black dot appears in the center of the point of contact of the flame

with the metal, note how far the torch tip end is from the metal. This distance is the length of the inner cone.

When butt welding aluminum, hold the torch at a 45° to 60° angle and dip the filler rod in the center of the puddle with an up and down motion. The inner cone of the flame is never to touch the aluminum bare metal or the filler rod. Do not stir the puddle or push or pull the filler rod through the puddle.

To make a lap weld hold the tip at almost a 90° angle to the line of weld and tilted about 60° up from the surface of the weld. When adding the filler rod in this case push the puddle back toward the trailing edge of the puddle with the filler rod. Keep the filler rod at the edge of the upper piece of aluminum at all times to prevent it overheating.

When tee welding, hold the tip equally between the two pieces and at a 60° angle to the line of weld. Push the puddle toward the back edge of the puddle when adding the filler rod.

Flange welding is also a very popular type of aluminum weld seam. Filler rod may or may not be used. Occasionally three pieces are welded in this way *(Figure 132)* and one must be careful in this latter case to concentrate the heat on the middle piece as it requires the greatest amount of heat. A larger than normal tip may be used when welding aluminum as it may be cut down (gas flow reduced) without the danger of backfire. To insure fusion all the way across the thickness of the metal when flange welding, the weld should bulge a little (it should be a little wider than total thickness of the two or three sheets). Very little torch motion, if any at all, is used in the above welds.

The flux used for welding aluminum contains chlorides and occasionally fluorides. The fumes from the flux are, therefore, irritating and the aluminum should be welded only in well ventilated places. This flux is also irritating to one's skin and harmful to clothing and must be carefully handled. Keep the flux in air tight containers when in storage. The flux should be mixed with pure water to a paste consistency and added to the filler rod only with a clean brush. Never contaminate the flux with dirt, rust, etc., and keep the brush in the flux bottle when not in use, never lay it on the bench or this will ruin the flux. It is important to use a good, fresh, aluminum flux at all times. The finished weld, in addition to all the usual appearances of a good weld, should be of a color similar to the filler rod material with a bright, shiny surface. If the metal is over-heated and oxidized, the color becomes darker and the metal has a dead white appearance with a rough surface.

A slightly carbonizing flame may be used for aluminum welding to insure that the metals will not be oxidized. An excessive amount of carbonizing flame will give the weld a dirty appearance. Flux should be washed from a weld with water or better with a sulphuric

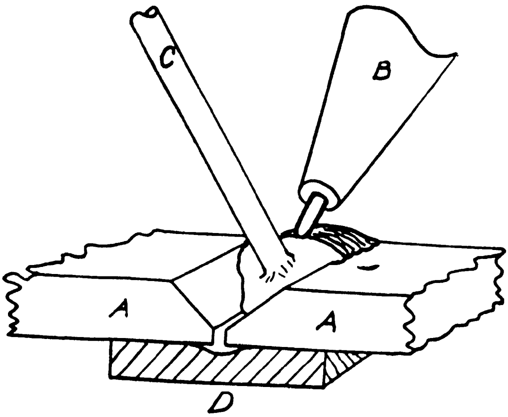


Figure 133. Welding cast aluminum: A. Cast aluminum, B. Torch, C. Aluminum filler rod, D. Back up material

acid water solution as soon as possible as flux left on the weld will have a corrosive effect. A student will find it very convenient to use backing material when first learning how to weld sheet aluminum. When welding aluminum, nickel, etc., one must, if possible, use holding jigs backing up surfaces because these metals become

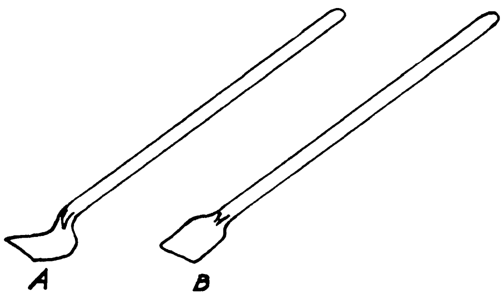


Figure 134. Cast aluminum steel paddles: A. Spade type, B. Straight type

very weak just prior to their melting temperatures. This is called "hot shortness."

152. Arc Welding Sheet Aluminum

Aluminum may also be welded with the electric arc. Heavily coated electrodes (5% silicon) used with reversed polarity and a close arc (20Y) make this type of welding entirely practical. Metal

of less than $\frac{1}{8}''$ thickness is difficult to arc weld and great care must be taken. The metal should be backed if possible. Always change the flux and then wash the weld with a 10% nitric or sulphuric acid solution to prevent corrosion of the aluminum, then wash with warm water.

Figure 135. Welding a lead battery plate to a collector strap. Note the steel form, the torch position, and the lead filler rod just being added

153. Oxy-Acetylene and Arc Welding Cast Aluminum

Occasionally an operator encounters a project which involves the welding of cast aluminum articles such as light frame work, cooking utensils, and metal decorations. As in sheet aluminum welding, a neutral flame is recommended in addition to the use of a fresh, chemically-pure flux. To prevent the sagging at the joint while welding, use carbon, copper, or steel blocks to back up the weld. *Figure 133.* Some very valuable aids for aluminum welding are: first, use a steel paddle to stir up the molten metal; second, remove the oxidized aluminum (scum) from the weld; third, smooth

out the surface. These paddles are usually made from quarter-inch steel, filler rods, flattened at one end into a flat spoonlike shape. *Figure 134.* When welding large aluminum castings the casting should be preheated to 500°-600° F. This temperature may be eas-

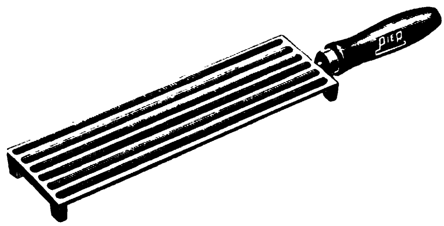


Figure 136. Die casting filler rod mold
(Courtesy of: Pier Equipment Mfg. Company)

ily checked by heating the casting until it will char a soft pine stick touched to the surface. See Paragraph 176 for details of construction and operation of a preheating furnace. Thicker sections should be chamfered as is done with steel. In addition the beveled edges

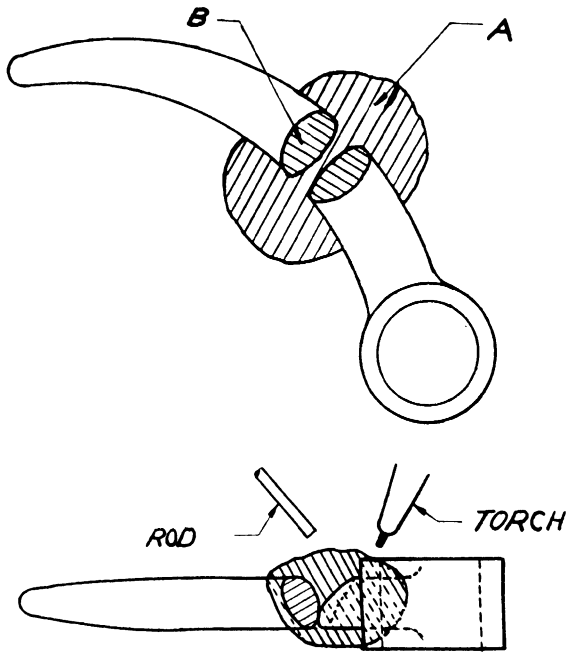


Figure 137. Preparing a die casting for welding: B. Ground casting fracture, A. Carbon, clay or asbestos mold

should be notched with a chisel or hacksaw (every 1/8"). This enables the edges to reach the welding temperatures without heating the adjacent metal too much.

Coated aluminum electrodes may also be used for welding aluminum. Reversed polarity and a short arc are primarily essential for a good weld. The flux must be thoroughly removed after welding.

154. Welding Aluminum Alloys

Duralumin (dural) (17S alloy) may be welded using an aluminum-silicon filler rod and dural flux (although aluminum flux may be used), but the finished weld will be very brittle and will not be able to withstand shock. The procedure is identical to welding aluminum. Welded dural should be heat treated after welding otherwise the weld will not be as strong as the parent metal.

155. Welding Lead

Lead is a very ductile metal having a high resistance to corrosion by certain chemicals. It is therefore used as a metal for tanks, cylinders, and as lining material for containers used to hold these corrosive chemicals. The most common use for lead welding is in connecting the parts of the automobile storage battery.

The procedure to follow when welding lead is very simple. Using an oxy-acetylene torch and a cast filler rod, the metal edges are cleaned and then fused together by an operation exactly similar to steel welding. The lead does not change color upon becoming molten, but this offers no serious difficulties. The joint should be backed, if possible, to prevent sagging of the metal upon securing penetration. Inasmuch as lead melts at approximately 620° F., the welder will be likely to overheat the weld at first. No flux is needed for this type of welding. *Figure 135.*

156. Welding Die Castings

Die castings are metal-alloy castings (sometimes called white metal) cast in iron and steel molds (dies) under high pressure. The same die (or mold) may be used many times and the finished article requires very little machining or finishing. Die castings may be cast to an accuracy of .001 of an inch. Die casting alloys are either alloys of high zinc, high aluminum, or high lead. These castings are brittle and break rather easily, but because of the ease of manufacture, many articles are now being made this way. The brittleness produces considerable demand for repair welding of these castings.

To weld a die casting successfully, one should know the constituent metals in the alloy. Most die castings have a high zinc con-

tent, which is a very difficult metal to weld because of its low melting temperature and rate of oxidation. Some typical alloys are as follows:

	Alloy No. 1	Alloy No. 2	Alloy No. 3
Zinc, %	85		
Aluminum, %	3		
Copper, %	4	1	4-15
Tin, %	8	4	70-90
Antimony, %		15	Trace
Lead, %		80	
Melting Temperature °F.	852	550	675

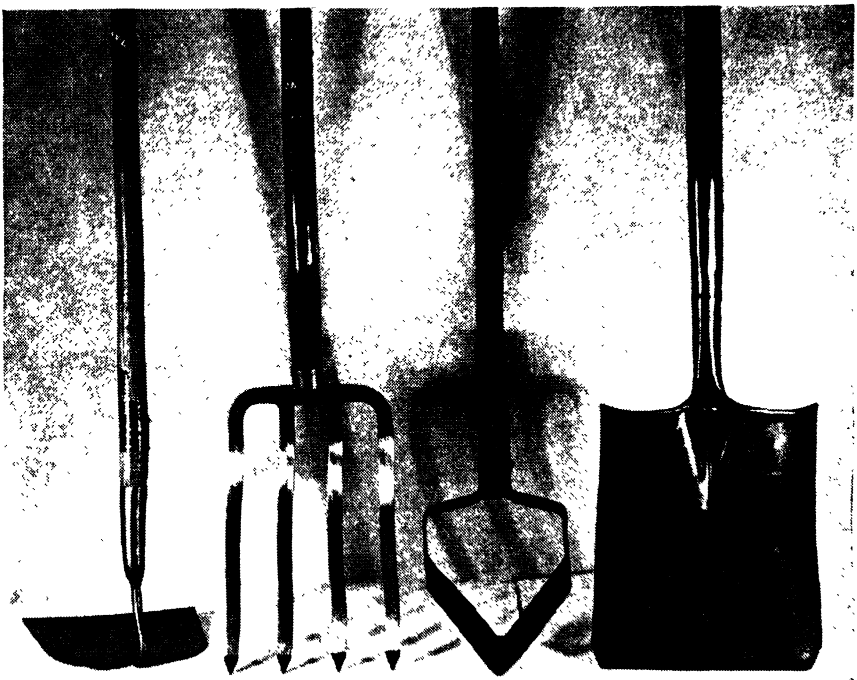


Figure 138. A hard surfacing application. Colmonoy Sweat-on Paste applied to excavating tools with an oxy-acetylene torch
(Courtesy of: Wall-Colmonoy Corporation)

The filler rod should be of the same composition as the original metal, if possible; although one may purchase die casting filler rods for general repair. The welder may also make his own filler rods by melting old die castings and using a stick mold. *Figure 136.*

The die casting is prepared for welding just as other metals. It must be chamfered if it is a thick section. It must be thoroughly

cleaned, and it must be backed up with carbon paste or blocks if possible. A neutral flame should be used and the usual welding procedure is followed. One must be careful because the metal melts before it changes color. The welder may use a steel paddle to smooth the surface of the weld and to remove oxide inclusions. *Figure 137.*

Another successful method of repairing die castings is to use a soldering copper to melt the metal. An oxy-acetylene torch is used to keep the body of the copper at a real heat while the point of the copper heats the die casting and fuses the two pieces together. The torch flame is not put on the die casting at all unless the casting requires preheating. This method is especially successful on small sections.

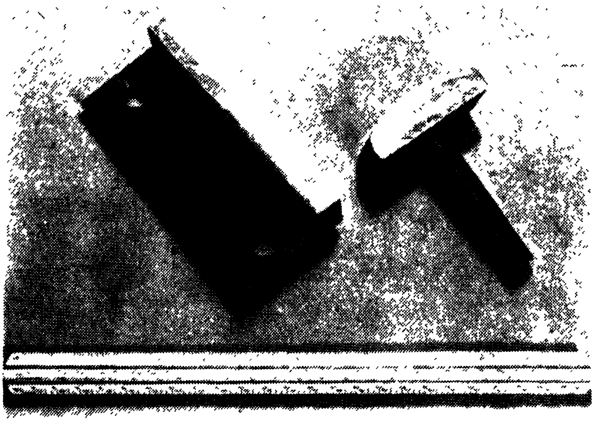


Figure 139. Shear blades with a hard surface cutting edge
(Courtesy of: Wall-Colmonoy Corporation)

157. Hard Surfacing

Hard surfacing is accomplished by adhering some hard metal to the softened metal body. This practice enables one to build a wear resistant, hard structure without great expense or sacrifice of shock resistance. Many alloys are available. Stellite is composed principally of cobalt, chromium and tungsten; Haystellite is made of cast-tungsten-carbide alloy; Hascrome is an alloy of chromium, manganese, and iron. Others, such as Colmonoy, Toolweld, Abrasoweld, Wearweld, Hardweld, Mangaweld, Stoody, Stoodite, Borod Stoodix and Colmonoy, are popular hard wear resistant alloys. These metals are usually fused to some softer metal such as mild steel. A coating of from $\frac{1}{16}''$ to $\frac{3}{16}''$ is used to provide the hard surface, while the steel-base metal supplies the strength. Stellite is an extremely hard metal and the only way it may be finished is

by grinding; even this method cannot be used too extensively, as the grinding wheel wears faster than the surfacer. The metal is also corrosion-resisting which enables it to be used in machines handling corrosive materials. *Figure 138.*

It is applied in oxy-acetylene practice by heating the roughened base-metal surface to a cherry red (Bright) with a slightly carbonizing flame.

Arc welding deposits of hard surface, wear resistant, and corrosion resistance metals is done as follows. Use reversed polarity unless directed otherwise, keep the voltage to a minimum (20V) and melt the base metal as little as possible. It is recommended that the surface be roughened before welding, that the deposit be at least 1/16″ thick and that welding be done in a flat position. *Figure 139.*

158. Review Questions

1. What is meant by deoxidizing copper?
2. Why is the "hot shortness" temperature of aluminum important?
3. What are the alloy metals of brass?
4. What are the alloy metals of bronze?
5. What two main characteristics of aluminum make it difficult to weld?
6. Is a flux necessary in welding copper?
7. Does one use a larger tip for welding quarter-inch copper plate than for quarter-inch steel plate?
8. List the constituents of the average aluminum weld flux.
9. What happens if brass is over-heated?
10. Describe the type of flame used when lead welding?
11. Is penetration necessary when welding a sheet-aluminum, butt weld?
12. How are the oxides eliminated during the bronze welding process?
13. Is it possible to machine Stellite?
14. What metals are usually used for soft surfacing?
15. What is the difference between sheet aluminum and cast aluminum?

CHAPTER X

PIPE AND TUBE WELDING

Pipes and tubes are mediums whereby fluids of all kinds may be carried from one point to another. The term fluid includes substances in the liquid or gaseous form. The term "pipe" usually refers to hollow cylinders made from flat stock, rolled, and welded into form. The thickness of a pipe is usually such that it may be threaded. The term "tube" usually refers to hollow cylinders, having a thin wall, and being made of seamless or drawn construction.

159. Types of Pipes

The most popular application of the pipe for carrying liquids is the water piping in a residence, or in a business building. The plumbing work in these buildings is commonly assembled out of low-carbon, steel pipe. Many oil companies and factories use pipe to convey oil and other fluids around the premises. In all power plant installations and heating installations, the water and steam are carried to the proper places by means of pipes. The common practice for many years was to connect the sections of pipe to the proper fitting, or to each other, by means of the Briggs Standard Pipe Thread. These threads, being of a tapered construction, are self-sealing and make a very tight joint. However, the cutting of the threads on the different sections of the pipe necessitates considerable labor; also the cutting of the pipe to accurate lengths necessitates considerable skill. The size of the pipe is measured according to its inside diameter, and the thickness of wall depends upon the diameter of the pipe. The larger the pipe, the greater the wall thickness. There are several standard constructions of pipe.

1. Cast iron
2. Wrought iron
3. Single strength, low-carbon steel
4. Double strength, low-carbon steel
5. Copper and brass pipe

Cast iron pipe naturally is a seamless pipe formed in a mold; the properties of cast iron are such that the sections of the pipe cannot be fastened together by means of threads, but must be connected

by the shoulder type of construction, limiting the use of cast iron to low pressure installations, such as drainage work, etc.

Wrought iron pipe is made of an iron with practically no carbon present, but slag is usually found in the material. This pipe may be threaded, but it cannot stand up under excessive pressure because of the fact that the pipe is made by rolling flat stock into a cylindrical shape; and the seams are either press welded or arc welded.

Mild steel and double strength pipe may either be seamed or seamless pipe. The seamed pipe is fabricated just as the wrought iron pipe explained above, but the seamless pipe is fabricated from solid bar stock, and the pipe is drawn through special dies. Seamless pipe has considerably more strength and can be used for much higher pressure work than seamed pipe. The double strength pipe uses the same carbon steel, but the wall thickness is greater. This pipe is used for high pressure refrigerant lines, and for high pressure steam lines.

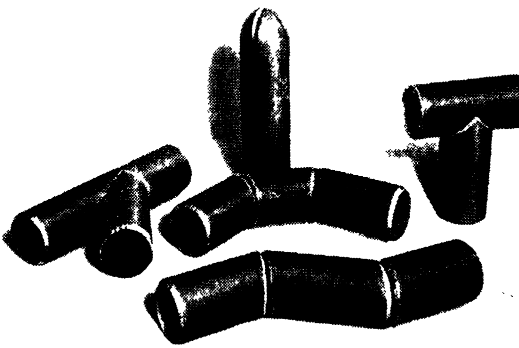


Figure 140. Pipe fittings ready for welding
(Courtesy of: Air Reduction Sales Company)

The industry now has available an alloy steel pipe which may be used in places where corrosion is an important problem.

Lead pipe has been used extensively in chemical plants where corrosion is an important consideration. It has also been used in water-pipe work. Lead pipe may be welded; or the plumber's sweat joint may be used to fasten the parts together. During the last few years copper and brass pipe have come into extensive use for water and refrigerant lines. This pipe is usually connected by means of the soldered joint, using "streamline fittings."

160. Tubing

Tubing is usually flexible and threadless. The most popular metal

used in the construction of tubing is copper. In the fabrication of automatic machinery, in refrigerating systems, in automobiles, and in places of extreme vibration, tubing is found to be the only satisfactory method of transmitting fluids. When the direction of the run is changed, the tubing may simply be bent to conform with the change in direction, whereas pipe necessitates the use of appropriate fittings. Tubing is obtainable in different strengths, and is also manufactured in both the seamed and seamless construction.

A recent development in the plumbing, heating, and refrigeration industries is the use of copper pipe. Copper pipe is non-flexible, heavy-duty piping, having a wall thickness somewhat less than steel piping; its size is based upon its internal diameter. Copper pipe is used extensively in plumbing work. However, its test pressure of approximately 800 pounds per square inch prohibits its use in very high pressure work. The joints made in copper pipe are usually soldered, as the thickness of the copper makes it difficult to thread the copper pipe. The aircraft industry uses special, seamless, steel tubing of special alloy. Aircraft tubing is seldom bent and is joined by welding.

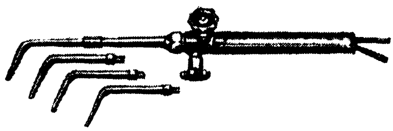


Figure 141. A light duty torch. Very popular in aircraft work. Note the torch valves located at the tip end of the handle to enable easy flame adjustment
(Courtesy of: Imperial Brass Mfg. Company)

161. Methods of Joining Pipe

Steel pipes may be joined together, or joined to fittings by several methods:

1. Pipe threads 2. Flange fittings 3. Welding

The method of joining by threads has been previously explained.

The flange method incorporates the use of threads, but the final connection of the two sections is by means of from two to ten flange bolts, which clamp the flanges together with a gasket between the two. This construction is popular in threaded pipe installations where it is thought that dismantling might occasionally be necessary.

The welding of pipe joints is a very popular means of making a pipe installation. The advantages of welding piping are neatness, compactness, rapidity, and low cost. *Figure 140.* The one disadvantage of welded piping is the difficulty of dismantling. However,

this occasion arises very rarely and may be arranged for by using flanges. Pipe welding may be performed by either the oxy-acetylene or the arc method.

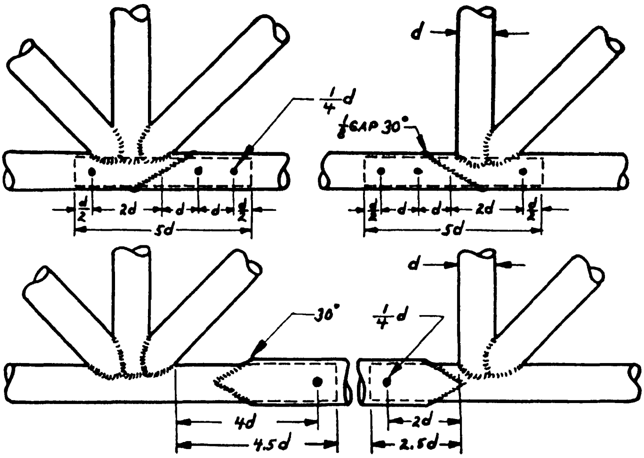


Figure 142. Aircraft tube longeron repair welds. D is the diameter of the tubing. The dimensions are approximately the repair standards used by the C.A.A.

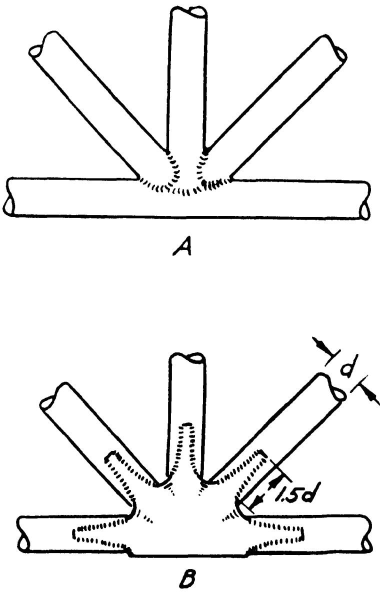


Figure 143. Aircraft tubing welds: A. A cluster weld, B. A repair gusset welded to an injured cluster welo

162. Methods of Joining Tubing

Tubing joints are made by one of several different methods.

1. The compression fitting
2. The flared fitting
3. Soldering
4. Brazing
5. Welding

Compression fittings and flared fittings are used in small copper tubing connections; the compression fittings are commonly used with the seamed type of tubing (automobiles), whereas the flared connection is used where seamless tubing is used (refrigeration).

The soldered connection utilizes special fittings, having receptacles accurately sized for the tubing insertion. The solder is admitted between the tubing and the fitting, where it forms a very thin film and strongly binds the two pieces of metal together. The soldered connection may be used for the seamed tubing, the seamless tubing, or for copper pipe.

The brazing and welding of copper tubing, or copper pipe, is very rarely done; but when it is performed, no special difficulties are encountered. The brazing of copper tubing and pipe occurs when the metal is to be attached to a different metal, or where corrosion is possible. Where copper pipe is to be attached to a copper fitting, or to another section of copper pipe, the joing may be welded.

163. Aircraft Tubing

The oxy-acetylene welding process is usually used for aircraft steel tubing. A special division of tube welding has been created by the aircraft industry. Special alloy tubes are used in the fabrication of the fuselages, the empennage, landing gears, and the wing sections. A light duty torch is commonly used for the work. *Figure 141.* This tubing is always of seamless construction, and is made of a very good quality of steel with some strengthening, alloying metal added. Such steels as chrome-molybdenum (1% chromium, 8¼% molybdenum), etc., are quite commonly used for this type of work. The tube has a relatively thin wall as compared to the ordinary steel pipe. The tubing is usually welded together by means of the oxy-acetylene process. To weld aircraft tubing, one usually heats the tube to a red heat, adding the filler rod, and then fusing the filler metal to the base metal. Good fusing with an absolute minimum of penetration is desired, and very light torches are used for this work.

Because a maximum of strength must be obtained when welding the joints of aircraft tubing, special fabrications have been developed. The most common types of special aircraft tubing joints are:

1. Fish-tail weld
2. Telescope tubing weld
3. Gusset weld
4. 90° Tee weld
5. 45° Tee weld
6. Cluster tube weld

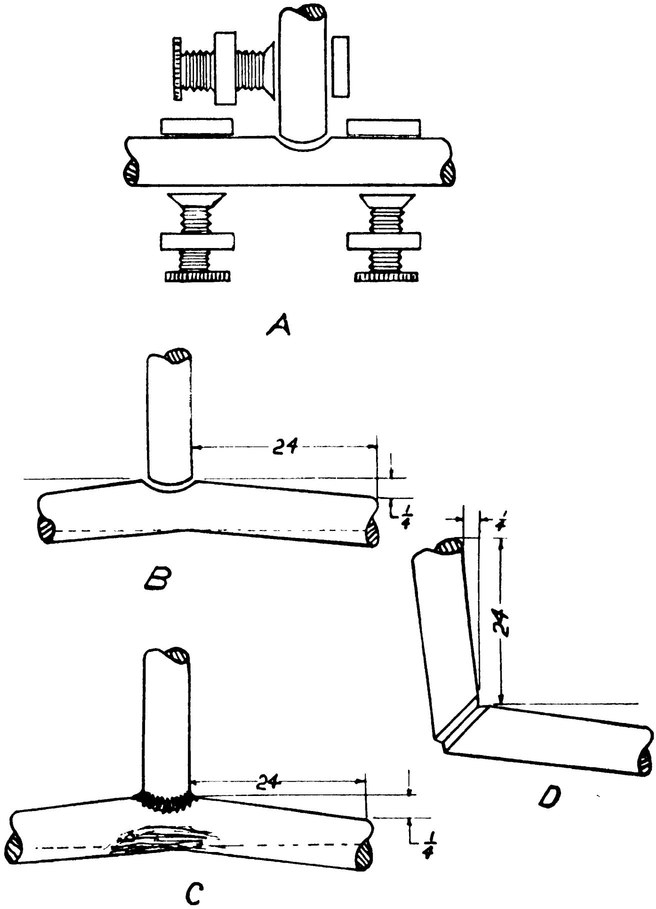


Figure 144. Methods of aligning pipe while welding: A. Pipe in fixture, B. Prebent pipe, C. The shaded portion indicates the place to reheat the pipe if it buckles during the welding, D. The amount to set an elbow joint out of line to obtain a 90° bend after welding

The fish-tail fitting is a strengthening, or repair joint, where the larger tube is cut into a V shape and then slipped over the small tube which it is to strengthen. The weld is a lap joint; the heated portion of the tube, where the weld occurs, is spread over a considerable length of tubing, thereby distributing the load along one

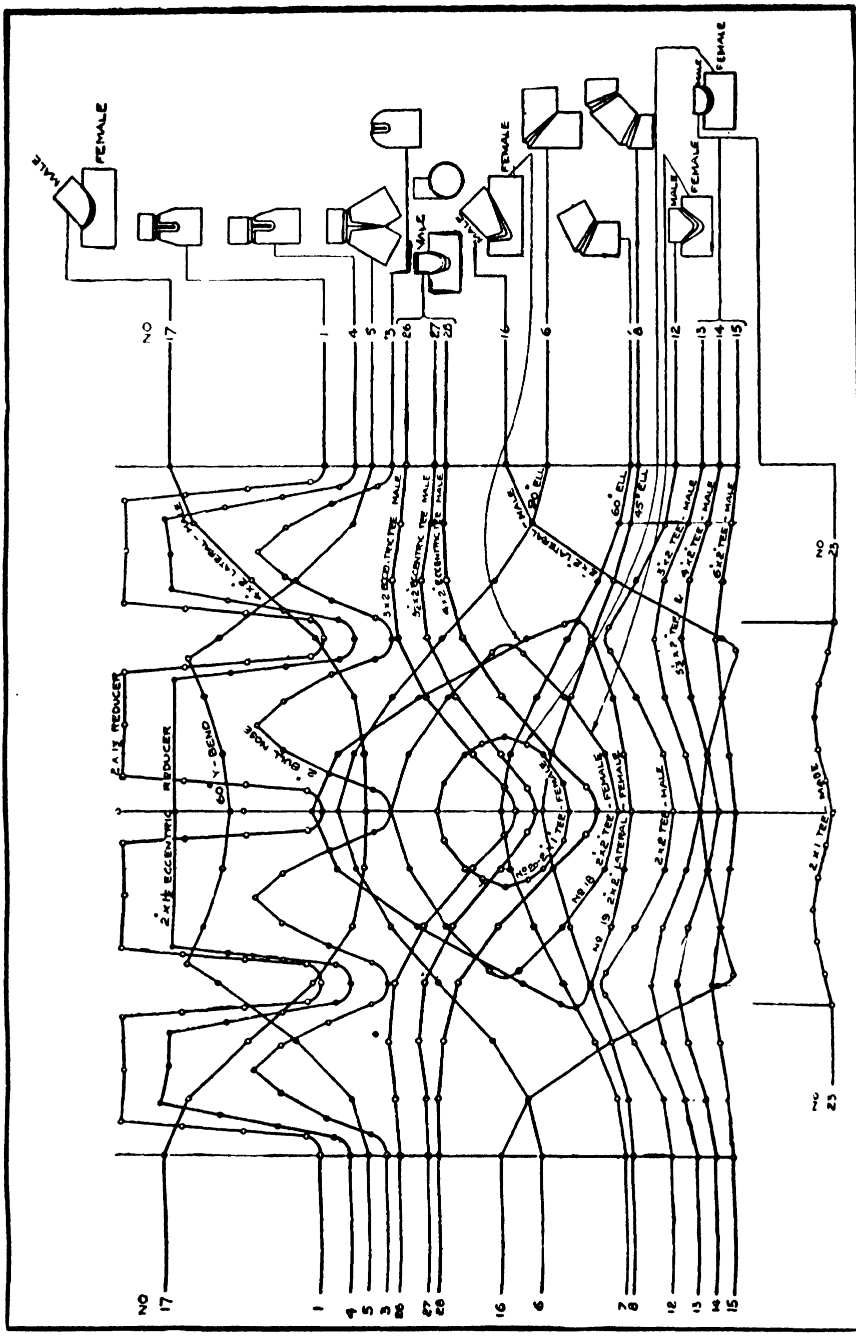


Figure 145. Pipe cutting curves
(Courtesy of: Air Reduction Sales Company)

or two inches of the weld. *Figure 142.* The telescope weld is used when a long column of tubing is welded near the end. If a simple butt joint weld were used, the joint might fail under bending; but by telescoping the tubing at the joint, additional strength is obtained, thus preventing this failure.

The gusset type joint is used where two or more tubes come together, at more or less of an angle from one another. The gusset is a piece of flat steel which is fitted into slots cut in the tubing at the juncture of the tubings. The tubing ends are then welded together where they come into contact, and the steel plate is also welded to the tubing, forming an extremely strong joint under tension, compression, and bending loads. *Figure 143.*

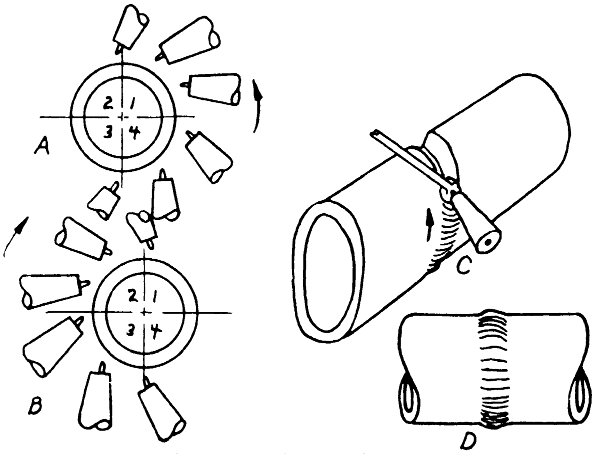


Figure 146. The fixed method of welding pipe: A. Starting underneath and progressing to the top on one side, B. Starting underneath and progressing to the top on the other side, C. Portion of torch and filler rod, D. Appearance of finished weld

The only accurate way to test aircraft-tubing welds is by the X-ray method. However, many companies periodically test samples of weld made by their welders. These samples are tested to destruction to determine both the quality of the weld, and the welder's ability. One of the greatest problems encountered in aircraft-tubing welding is the corrosion which takes place inside of the tubing at the point where a weld has been made. To prevent this corrosion it is a common practice to coat the inside of the tubing with hot linseed oil, or linoil, which prevents any further rusting or oxidation at the weld. One difficulty encountered with all pipe and tube welding is the alignment of the pipe or tube after welding. The best method is to clamp the pipe or tube in place while welding, and allow it to cool before removing the clamps. Another method is to allow for

the contraction of the joint metal by providing for a ¼″ movement of the pipe for each 24″ of length (approximate). *Figure 144.*

164. Code Requirements

Special applications of welding piping, steel tubing, copper tubing, and copper pipe in certain localities are covered by a code necessitating certain requirements to be met before the welds may be used in installations. These requirements usually concern high-pressure work of all kinds, including steam and air, or where corrosive fluids are carried; but in aircraft work the National Government maintains a crew of inspectors who judge whether the welding of the aircraft tubing is sufficiently well done to permit its use. The Hartford Insurance Company requires that all welding, which is done on property that they have insured, must be done by men who have passed a special test conducted by their company.

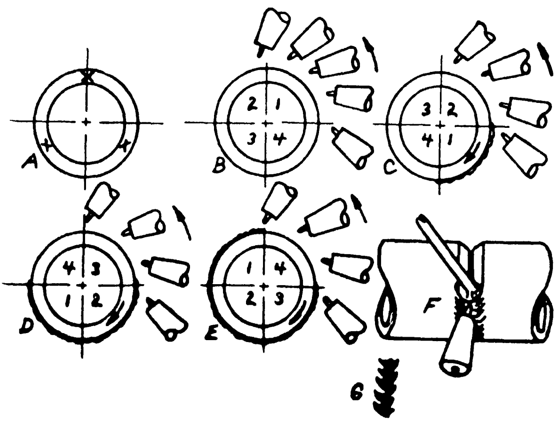


Figure 147. The rolling method of welding pipe welding: A. Three tacks 120° apart, B. First part weld, C. Pipe rolled and second quarter welded, D. Pipe rolled and third quarter welded, E. Pipe rolled and fourth quarter welded, F. Position of torch and filler rod, G. Weaving motion used

165. Pipe Welding

The method of welding pipe is dependent upon the kind of pipe, the size of the pipe, and the location of the weld. Many types of joints are encountered in pipe welding. These include butt welds in all positions, elbow pipe connections, and the adapting of different sizes of pipe. Pipe welding of a more simple nature, and on smaller sections of pipe may be done on automatic machines. These machines are constructed in two types: (1) where the flame travels around the pipe and welds the metals together, (2) more commonly the pipe is rolled and a fixed flame performs the welding.

However, for irregular joints and for final assembly, hand-welding is the only method available.

Standards have been established which determine the construction of the weld bead for certain sized pipes. The requirements are based upon the fact that these welded joints must be at least as strong as the original pipe. Pipe greater than one-eighth-inch, wall thickness must be specially prepared for welding; all these special

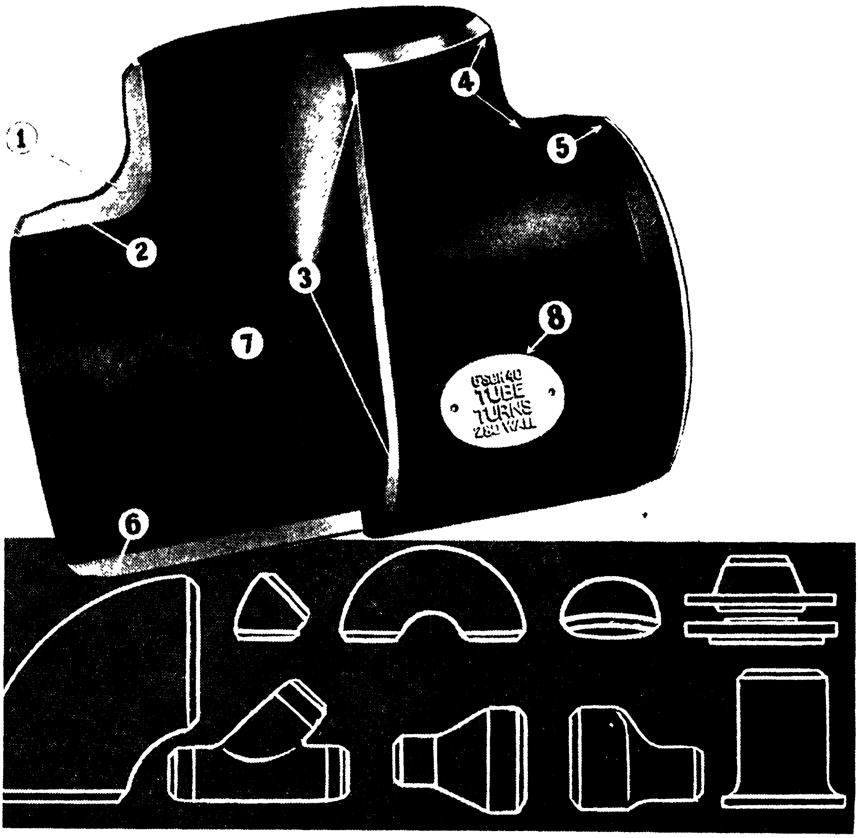


Figure 148. An available pipe joint fitting: *1* Extra thickness; *2* & *3* Reinforcement; *4* Longer outlets; *5* Ends machined; *6* Extra thickness; *7* Smooth inside walls; *8* Label
(Courtesy of: Tube Turns, Inc.)

joints must have special contours cut into the pipe in order to permit accurate fitting. This pre-fabrication of the pipe is performed by means of the cutting torch. (See Chapter 13.) The actual welding of the joint may be accomplished either by the arc method or by the acetylene method. It usually requires the use of a fluxed elec-

trode to perform a satisfactory arc weld, but some codes prohibit the use of arc welding for extremely high-pressure welding.

166. Use of Templets and Layout of Pipe Joints

The cutting of pipe to fit one another when the pipe is placed at various angles necessitates knowing the irregular curves of the contact. To draw the guide lines for these curves, several methods are used. Paper or sheet metal templets laid out on a drafting board and cut out for shop use are common practice. *Figure 145.* Special devices are also used to determine the shape of the curves. One is placing the pipe in its proper alignment and laying a soapstone pencil on the pipe and sliding it around the pipe to mark both the opening shape and the shape of the pipe end. Mechanisms may be purchased to aid in marking pipe.

167. Oxy-Acetylene Pipe Welding

When welding with the oxy-acetylene torch, three important things must be observed before the final welding operation may be performed.

1. The pipes must be accurately cut to fit one another.
2. The metal must be beveled, or chamfered, to insure accurate penetration and maximum strength. The chamfering may be done with a cutting torch. Some high-pressure lines specify, however, that the chamfers must be machined or chipped.
3. The joint must be carefully tacked to insure proper alignment of the piping.

The pipe should be tacked in three places around the periphery. When the actual weld is being done, these tacks should be rewelded; also the end of the weld should run over the beginning of the weld about 1″.

After the preparations have been completed, the weld proper is performed by one of two methods.

1. The pipe may be held stationary, and the welding done by starting at the bottom and working up both sides of the pipe. *Figure 146.*
2. If feasible, the pipe is rolled, or turned gradually, as the welding progresses so that the part being welded is uppermost at all times (position welding). *Figure 147.*

Of the two, the latter insures a better weld. However, only in rare cases may this type of welding be utilized for the complete job. Usually both methods are employed on one assembly of pipes.

The size of torch tip to be used is determined by the thickness of

the pipe wall, and is practically the same as for the same thickness of sheet or plate. The weld proper may be done either by using a forward weld, or as many companies recommend, the backward weld may be used. One procedure recommends that the backward method of welding be used in combination with the carbonizing flame and a special filler rod. It is extremely important that penetration be secured when welding a pipe. The weld should also be "built-up" a definite amount. Experience has shown that a penetrated weld, sufficiently "built-up," has more strength than the original metal, and will withstand more wear and corrosion than the original metal. If the piping is for high-pressure work, the

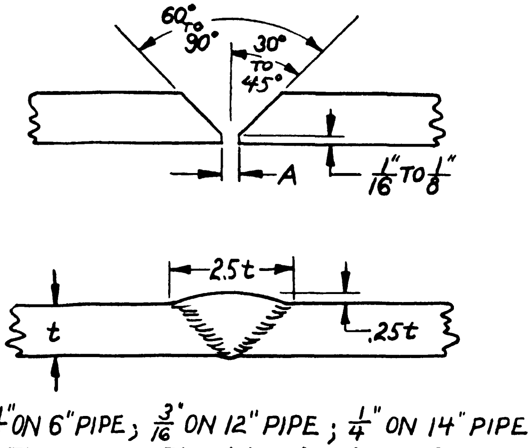


Figure 149. Pipe joint chamfer angles

joint must be annealed. Special, high-frequency, induction furnaces are now available for annealing each weld as it is completed.

168. Forms of Pipe Joints

As mentioned in the preceding paragraph, the piping must be carefully prefabricated to insure strong and neat welds. Many companies now carry in stock elbows, adapters, tees, etc., which are especially manufactured for use in welding pipes. These items are ready to use because their form is accurate and the edges to be welded are chamfered. The types of weld fittings available to the pipe welding trade are "tees," 90° elbows, 45° elbows, welding neck flanges, concentric reducers, lateral nipples, straight nipples, eccentric reducers, saddle-cap, reducing tees, and 180° return bends. These fittings may be obtained in all sizes; any large wholesale pipe establishment carries these items in stock. One must be sure to specify the kind and the size of fitting when ordering them. *Fig-*

ure 148. When preparing pipe for the welding, the contour of the chamfer is very important. The angle of the chamfer is recommended to be approximately 45°, 60°, or 90° overall, or each side is to be chamfered approximately 22½°, 30°, or 45° from the vertical. The depth of the chamfer depends somewhat upon the thickness of the metal. *Figure 149.* Under no circumstances is it to extend through the full thickness of the metal, but instead should extend to within approximately 1/16″ apart to insure adequate penetration. A good method of preparing a butt pipe weld is illustrated in *Figure 150.*

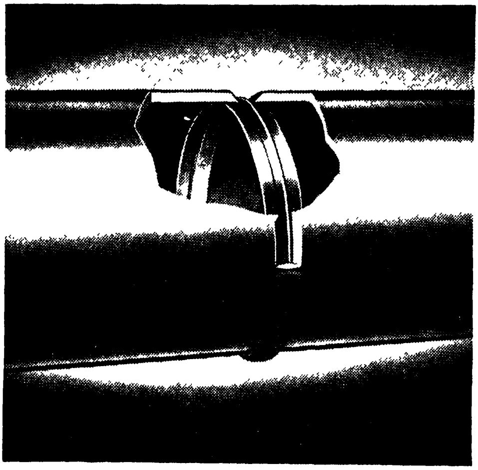


Figure 150. Use of a backing and aligning fitting for a pipe butt weld
(Courtesy of: Tube Turns, Inc.)

Many times, however, a pipe welder is forced to fabricate or manufacture his own fittings, or to prepare special joints when connecting pipes. A fundamental knowledge of geometry (especially descriptive) may be used to good advantage for this type of layout. Several practical methods have been developed, however, which solve most of the problems encountered.

One method is to assemble the two pipes to be welded together without doing any previous cutting. *Figure 151.* A pencil or crayon is then fastened to, or placed on the pipe which runs into the others. With the end of the pencil resting on the other pipe, and with the pencil kept parallel to the axis of the pipe it rests on, it is revolved or carried around this pipe. The pencil end will draw the shape of the opening to be cut in the pipe.

Usually, however, the correct shape of the joint is determined by preparing paper, or metal templeted from a layout drawing. *Figure 152.* When preparing these special joints, it must always

be kept in mind that provision must be made to allow for thorough penetration.

169. Inspecting Pipe Welds

It is important to know whether a completed pipe weld is of sufficient strength. In determining the ability of an individual welder, standard procedures have been developed for testing sample welds produced by a welder. However, on the final fabrication, or welding, of pipe joints it is impossible to actually determine the strength of the weld, as the ability of a welder may vary with fatigue. Therefore, superficial methods have been devised to determine the strength of the joint without destroying it. This type of testing

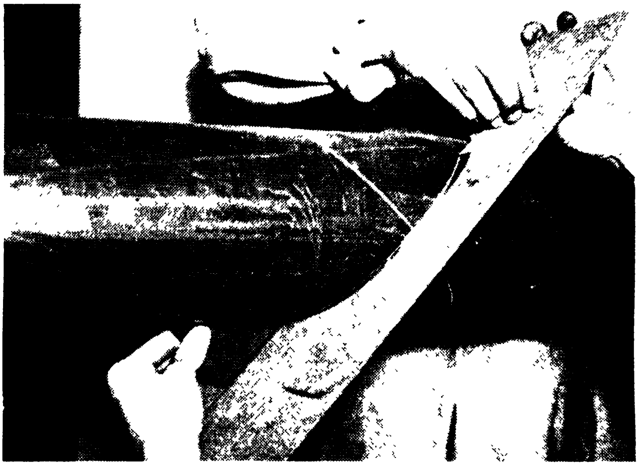


Figure 151. One method of determining the design of a pipe joint
(Courtesy of: Linde Air Products Company)

is usually called inspecting. Under the heading of inspection, the following qualities of the weld are observed:

1. Clean bead
2. Constant width of bead
3. Fusion of the added metal
4. The height of the bead
5. Presence of pits and spots in the weld

The method used to inspect a weld for sufficient height (build-up) of the weld, and for the width of the bead is to use a templet which is a steel form that fits on the pipe with a slight cavity on one edge. The cavity is of the shape, size, and contour of the correct sized weld. *Figure 106.*

Another inspection, which requires the use of very expensive equipment, is the X-Ray test. This inspection requires the use of an X-Ray machine; photographs are taken of the weld, or the weld

is looked at through the fluoroscope. Any distinct cracks, tacks, pits, or blow-holes underneath the weld surface are very quickly revealed by this means. All of the water mains in Boulder Dam were arc welded and then tested by means of the X-Ray method. This method tests the internal condition of a weld without destroying it.

Another method which has proved quite successful is the magnetic test (Magnaflux). An electrical coil is wound around a portion of the pipe adjacent to the weld. The coil is then energized, and iron filings are placed on the weld surface. Any weak surface spots or cracks in the weld are revealed by local north and south poles being formed, and a distinct collection of filings will denote a failure in the weld.

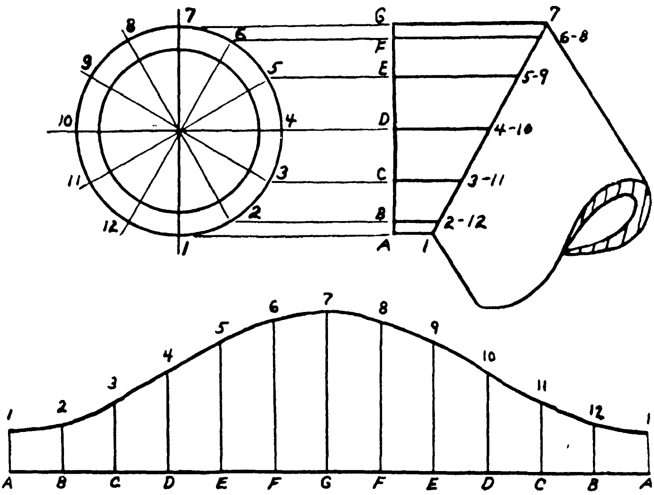


Figure 152. Preparing a paper or metal template (Layout)

Another test which is becoming quite popular is the slack lime test. A coating of slack lime is painted on the surface, and the weld is then subjected to a stress of approximately three-fourths its maximum stress. If the slack lime flakes from the metal evenly, the weld is all right. However, if some of the lime flakes away at certain points, this indicates a weak spot in the weld. The specific gravity test is another method to determine whether or not the weld is of good quality. The density of the added metal is determined, and this density should be of a certain specific amount in order that the weld may pass inspection.

Ordinarily the template test, when conducted by an experienced

welder, is taken as sufficient evidence that the weld is of good quality.

For a welder to work on high-pressure, fluid lines, such as a steam fitter, the welder must pass an examination to determine whether his welds are of good enough quality to withstand the stresses included in these high pressure lines. One of the best known of these examinations is the Hartford test, which is explained in Chapter 7. It is only after passing this examination with a good grade that this particular insurance company will insure a plant using welded pipe fabrication.

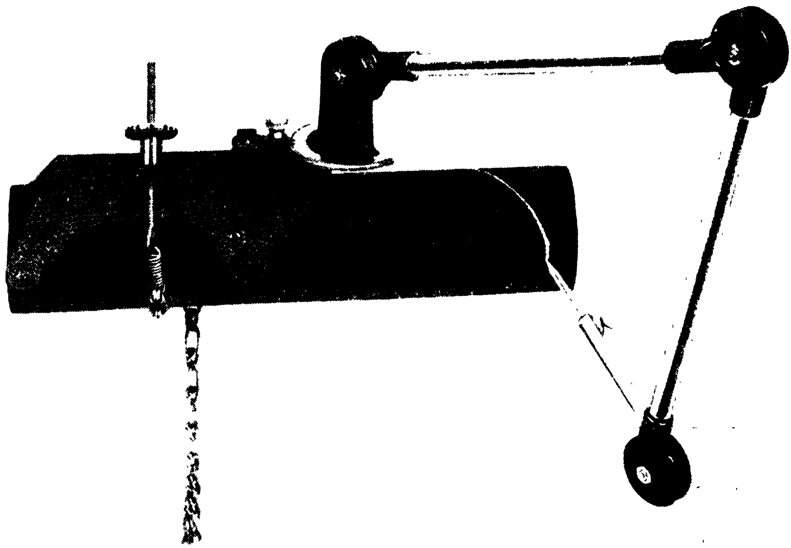


Figure 152A. A special method of determining pipe cutting curves
(Courtesy of: Tru-Line Corporation)

Practically all pipe welds are tested either under gas pressure (air or carbon dioxide), or under water pressure. The pressure imposed is usually twice the amount the weld is expected to be under when in actual use. The air pressure method will denote leaks when a soap solution is placed around the joint. The water method (hydrostatic) determines the strength of the complete joint. Of the two the gas method is more popular. When testing pipe-joint welds during the air pressure test, it is important that the pipe immediately adjacent to the weld be pounded vigorously with a hammer. This is done to dislodge any small scall (oxide) particles which might temporarily close a leak, but which would soon

allow a leak. Do not pound on the weld itself, as the peening action might temporarily close small pin holes which would eventually give trouble.

170. Summary

It requires considerable skill to weld pipe correctly. A pipe welder's ability should be periodically checked by testing samples of his welding to destruction to determine their quality. Pipe welding, when properly done, is faster than threaded assembly, and is stronger. Pipe welds should be vigorously inspected and tested. Penetration and build-up are absolutely essential to a successful weld.

171. Review Questions

1. How far apart should the ends of a pipe joint be placed prior to welding?
2. What are the two methods of performing the welding of a pipe?
3. What is the difference between tubing and pipe?
4. May tubing be welded?
5. What is aircraft tubing made of?
6. What is a gusset?
7. Explain the air pressure method of testing pipe welds.
8. What is the angle of the chamfer which is formed between two pipes to be butt-welded?
9. What method of welding pipe is also called "position" welding?
10. Should a pipe joint be tacked before welding?
11. How many tacks should be used on a 6″ pipe?
12. May a pipe be arc-welded?
13. Why shouldn't a pipe weld be peened before testing for leaks?
14. May a pipe always be chamfered by oxy-acetylene cutting?
15. Of what materials are pipe cutting templets made?
16. Should the chamfer extend through the thickness of the pipe?
17. Is a carefully welded pipe-joint considered as strong as the original metal?

CHAPTER XI

CAST IRON WELDING

Welding finds an important use in the fabrication of cast iron articles and the repair of broken cast iron parts. Cast iron is a very brittle metal; under the welding flame, or the electric arc, it behaves differently from most of the metals previously described.

172. Properties of Cast Iron

As the name implies cast iron is a casting made of iron and carbon with between 2.25% and 4% carbon. For certain purposes, alloy metals may be added to the cast iron. For example, nickel makes the casting more dense, nickel and chromium make the cast iron rust proof, while phosphorus makes the metal pour more easily (low surface tension), and cast more accurately. Cast iron is used extensively for heavy machine parts. Its melting temperature is approximately 2600° F.

173. Kinds of Cast Iron

There are three principal types of cast iron:

1. White cast iron
2. Gray cast iron
3. Malleable cast iron or malleable iron. *Figure 153.*

White cast iron is a casting that has been cooled rapidly (chilled) after it has been poured, or cooled rapidly after being heated above its critical temperature. The name, white cast iron, is given due to the appearance of the fracture. The metal is extremely hard and is very difficult to machine. Most welds on any type of cast iron will tend to have a white cast iron structure unless they are heat treated after welding or cooled slowly after welding.

Gray cast iron is cast iron that has been cooled very slowly from its critical temperature (in sand, asbestos, or in a furnace). The name is derived from the gray appearance of the fracture; the gray is the result of graphite flakes in a matrix of white iron and iron carbide. This metal is easy to machine; it is usually the policy of a welder to heat treat all cast iron welds, or to cool them slowly in order to make the weld machinable.

Malleable cast iron, or malleable iron, is a white cast iron that is heated to 1400° F. for 24 hours per each inch of thickness and then cooled slowly. This heat treatment permits the release of carbon from the iron and allows it to form small nodules, or spheres of carbon, in a matrix of low-carbon iron. The surface of the casting is first affected, and the length of the heat treatment determines the depth of the above change. Most malleable castings have the heat treatment extend only 1/8″ to 1/4″ into the metal. This heat treatment makes the casting stronger and more resistant to shock, fatigue, and vibration. Welding malleable iron will destroy this heat treatment and turn the metal into white or gray cast iron. Therefore the welding of malleable casting is not recommended. Malleable castings may be brazed, or bronze welded, quite satisfactorily.

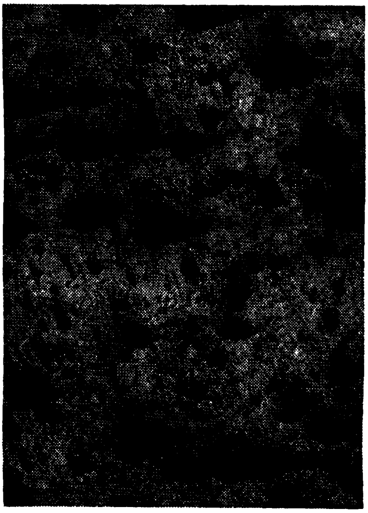


Figure 153. Malleable cast iron magnified

All cast iron weld-joints tend to become white cast iron; heat treatments previously administered are destroyed, and the casting must again be heat treated to bring back its original properties. Occasionally even this precaution will not be sufficient if the welder has allowed oxide spots to remain in the weld (poor procedure or improper flux). There is no satisfactory remedy for hard spots except to reweld them and remove the oxide inclusion.

174. Preparing Cast Iron for Welding

Cast iron may be prepared for welding much the same as steel. Thin pieces should be cleaned by grinding and then filing, whereas

thick sections, ¼″ or more, should be chamfered (beveled) at a 60° angle, leaving a ⅟₁₆″ blunt edge. *Figure 154.*

175. Methods of Strengthening a Cast Iron Weld

Occasionally the welder may prepare the cast iron seam in special ways to obtain a stronger joint than is obtained ordinarily. The methods used are to insert studs in the edges to be joined, which when welded, add materially to the strength of the weld. *Figure 155.*

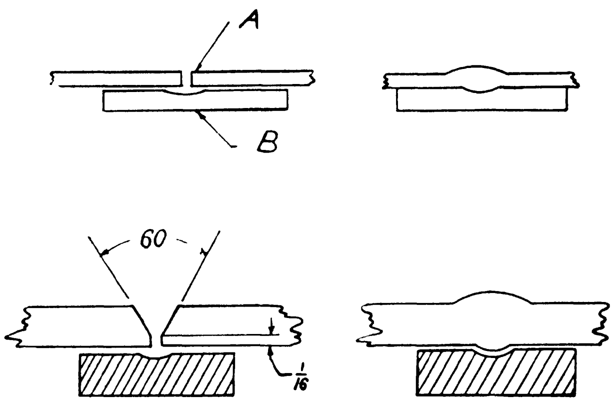


Figure 154. Preparing a cast iron section for welding: A. Base metal, B. Back up material

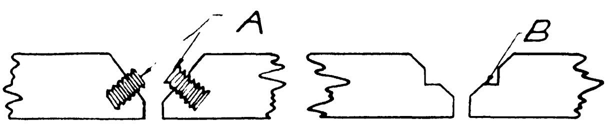


Figure 155. Methods of strengthening a cast iron weld seam: A. Steel studs, B. Notches

176. Preheating Cast Iron

Most cast iron objects must be preheated before welding to prevent cracking of the metal as the weld cools. This is due to the brittleness of the metal and to the fact that most cast iron welds are on complicated frames and structures, i.e., cast iron wheels or frames. This preheating also permits faster welding, and assures closer alignment of the structure after the weld is completed and has cooled. Preheating is done in a furnace, and the structure to be welded should be heated to a temperature of between 1500° F. and 2000° F. (a dull cherry red). If it is a simple structure, where expansion and contraction are freely permitted without producing undue stresses and strains, preheating is not necessary. If pos-

Figure 156. A preheating furnace in operation
(Courtesy of: Linde Air Products Company)

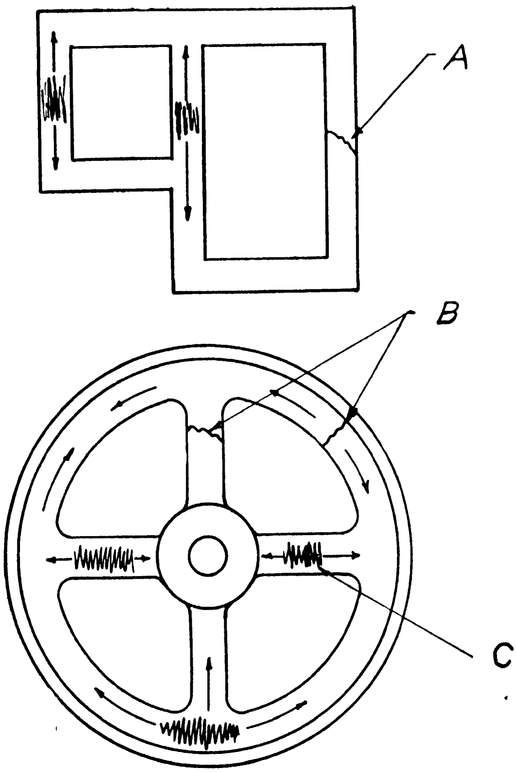


Figure 157. Local preheating of a structural cast iron body: A. The fracture, B. The fractures, C. The shaded zones represent preheated parts

sible, the welding should be done on the preheating furnace with the preheater operating. Fire bricks are usually built around the structure to be welded to retain the heat and permit quicker and more economical preheating. *Figure 156.* If a furnace is not available and preheating is necessary, this may be done with a torch, oxy-acetylene, city gas-air, city gas oxygen, gasoline air, propane-oxygen, and the like. By knowing what members to preheat most of the stresses and strains can be eliminated. *Figure 157.* If the casting is flat, it is best to weld it on both sides to prevent warping.

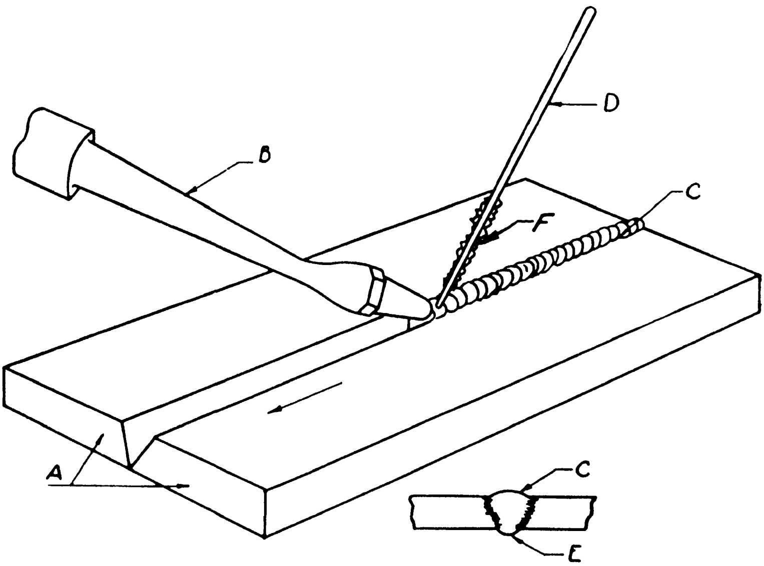


Figure 158. Welding cast iron by the oxy-acetylene process (backward welding): A. Cast iron, B. Torch, C. Build-up, D. Filler rod, E. Penetration, F. Flux

177. Oxy-Acetylene Welding Cast Iron

The sized tip used is similar to the size used for steel of the same thickness. A neutral flame should be used along with a cast iron filler rod of the proper size. Cast iron filler rods are available in 1/8″ diameter x 18″ length pieces, or 1/4″ square x 24″ length pieces. The parent metal must be cleaned of oxides. Use a file if possible. The torch should be held at a 60° angle with the seam, and the inner cone must not touch the metal. The flux should be added by coating the filler rod with flux and adding it to the weld. The flux must have the correct constituents; it must be fresh, and be moisture-free. In cast iron welding, it is imperative that the gas pockets and oxides be worked to the surface of the weld. This may be done

by stirring the molten puddle with the filler rod. The torch may be moved either forward or backward, usually forward for thin sections and backward for thick. The weld must have thorough penetration, and a slight crown is to be preferred. An oscillating motion is usually used, although no ripples are likely to appear on the surface of the weld. *Figure 158.*

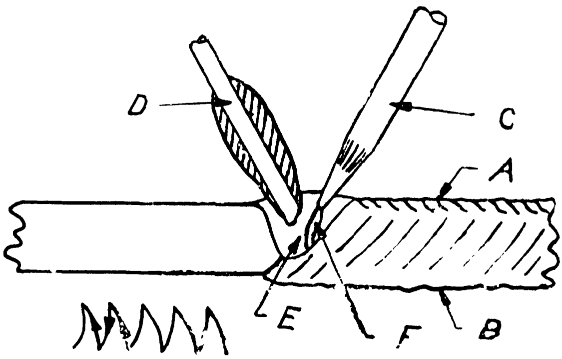


Figure 159. Welding cast iron by the carbon arc process: A. Bead, B. Penetration, C. Carbon electrode, D. The fluxed filler rod, E. The crater, F. The arc

178. Arc Welding Cast Iron

Cast iron may be welded with the carbon arc, or with the metallic arc. When using a carbon arc, the manipulation is the same as with the oxy-acetylene method. *Figure 159.* However, if the metallic arc is used, special coated steel electrodes are necessary, the

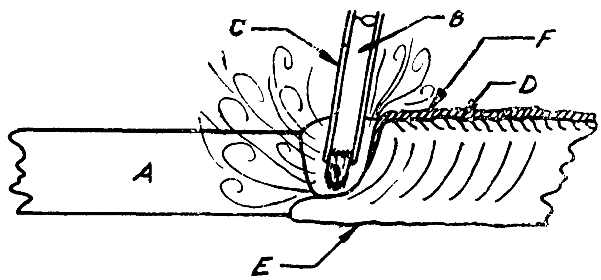


Figure 160. Welding cast iron by the metallic electrode arc process: A. Cast iron, B. The coated electrode, C. The flux coating, D. The bead, E. The penetration, F. The slag

steel usually having a nickel content. Steel studs are commonly used to make a stronger weld. The same motion, electrode size, arc length, etc., are used in cast iron welding as are used with the same thickness in steel welding. *Figure 160.*

179. Inspecting Cast Iron Welds

The finished cast iron weld should be slightly crowned, not undercut; it should have penetration but no pits or bubbles should appear on the surface of the metal. The width of the weld should be approximately three times the thickness of the metal.

180. Heat Treating a Cast Iron Weld

If a cast iron weld is allowed to cool in air, it will consist mainly of white cast iron, or at least a large number of these spots will exist. If cooled very slowly in sand, or in a brick housing, most of the weld will be gray cast iron, but some hard spots may still be included in the weld. To secure the best results, the whole structure should be heated to its critical temperature and then cooled very slowly. This latter practice is sometimes more expensive than the welding operation itself, but it does insure a good weld.

181. Testing Cast Iron Welds

Cast iron welds may be tested by inspection of the outer surface. However, the beginner should break sample welds along the length of the seam, and inspect the fracture for gas pockets, cracks, burned spots, and hard spots. A good weld will have none of these.

182. Review Questions

1. What is cast iron?
2. How may white cast iron be turned into gray cast iron?
3. What is the best method of repairing a fractured malleable iron casting?
4. Why should cast iron structures be preheated before welding?
5. May the backward welding method be used for welding cast iron?
6. Explain the purpose of steel studs when welding thick cast iron fractures.
7. Is cast iron more fluid or less fluid than steel when melted by a torch?
8. What is the melting temperature of cast iron?
9. Does cast iron contain more carbon than steel?
10. Is malleable iron more vibration resistant than white cast iron?

CHAPTER XII

SPECIAL FERROUS METAL WELDING

The growth and popularity of special forms of ferrous metals have necessitated the development of many new techniques in reference to the welding of these metals. The use of low-carbon-alloy steels for high-strength, light-weight construction, and the use of stainless steels for applications where appearance and corrosion resistance are important, has brought about many special welding problems.

183. Low Carbon Alloy Steels

Many articles which, until recently, have been manufactured from cast iron and steel castings are now being fabricated of steel. Many of these applications are found to be much more desirable, especially when a reduction in weight is possible. Cast iron and cast steels are approximately 60% as strong as ordinary steel. Low-carbon, alloy steels (alloy steels under .30% carbon) are 10% to 30% stronger than the straight, carbon steels, and are desirable where extra weight results in lost power. An example of this is a steam shovel bucket. Generally speaking, each pound that is saved in the weight of the bucket without reducing its strength, means that an extra pound of material can be handled without using any more power. One company was able to convert a 5-ton-capacity, steam-shovel bucket into a 6-ton-carrying capacity by changing the casting design to a fabricated low-carbon, steel-alloy design.

These alloy steels are slightly more expensive than the straight carbon steel, but by reducing the continual overhead (lost power) they are much to be preferred. The method of welding the low-carbon, alloy steel is very similar to that of straight carbon steel. However, if oxy-acetylene welded, flux should be used to counteract the oxidation on alloying elements, and filler rods of a composition corresponding to the base metal must be used. When arc-welding this metal, coated electrodes, especially recommended for these steels, should be used. While the expansion co-efficient of these steels slightly exceeds that of straight carbon steel, no special precautions need be taken in reference to warping, except in extreme cases. For the best results one should anneal the complete structure after all the welding has been completed. The main alloy elements of

these low-carbon steels are copper and nickel. The amounts of these are 4 to 6% copper and 3 to 7% nickel. *Figure 161.*

Type	C	Mn	Si	Cn	Ni	Mo	Cr
Cor-Ten.....	.10	.20	.70	.40	....	...	1.0
Man-Ten.....	.35	1.50	.22	.13	....	.20	....
Sil-Ten.......	.30	.70	.20	.13	....	...	....
Yoloy........	.15	....	...	1.0	2.0	...	....
RDS-1........	.12	1.00	...	1.0	.75	.20	....
RDS-1A......	.30	1.00	...	1.0	.75	.20	....
Hi-Steel.......	.12	.60	.30	1.1	.55	...	....
HT-50........	.12	.50	...	.55	.55	.15	....
AW-70-90A...	.25	.75	.25	.55	.25	...	....
AW-70-90B...	.25	.75	.25	.55	.25	...	.25
Jal-Ten.......	.35	1.50	.30	.40	....	...	.25
Gr City......	.14	.80	.18	.28	....	...	.12
Gr City 2.....	.25	1.40	.18	28	....	...	.12
Centralloy....	.15	.75	.50	.50	.25	...	.25
Konik.	...	....	...	.20	.35	..	.12

Figure 161. Table of low carbon alloy steels
(Courtesy of Champion Rivet Co.)

184. Stainless Steel

There are very many varieties of stainless steel on the market. Some of the most popular of these are the 18-8 stainless steel which consists of 18% chromium and 8% nickel with approximately 1/10 of 1% carbon. There are many others, most of them sold under trade names such as Allegheny metal, Endura KA_2, Rezistal KA_2, Duralloy 18-8, Bethadur No. 2, Colonial Stainless N, Unalloy, Neva-stain, U.S.S. 18-8, etc. Ascaloy is another stainless steel containing 14% chromium and 1/10 of 1% carbon. Another group of stainless steel contains 25% chromium and 12% nickel such as Allegheny, Armco 25-12, U.S.S. 25-12, Enduro HCH. A third major group consists of 18-8 alloys with a small amount of Molybdenum added. Some of these are known under such trade brands as Rezistal V_1A_2SMO, U S. Steel 18-8-S-MO, S-17 MO, etc. A fourth group of stainless steel (Iron and Steel Institute No. 310) contains 25% chromium and 20% nickel. The Iron and Steel Institute has developed a standard method of identifying the numerous stainless steels. *Figure 162* lists the name, the composition, and the identification number of the more popular ones. These stainless-steel alloys all require special composition rods to gas-weld or arc weld each of them.

Whether gas welded or arc welded, stainless steel must be kept

Kind of Steel	Per Cent of Metal				
	Chromium	Nickel	Mangine	Silico	Carbon
Chromium Steel..........	15	..	....	....	.10
Stainless Iron.............	13	..	.50	.50	.12
Stainless Iron............	16	..	.50	1.50	.12
18-8 Stainless Steel........	18	8	.65	1.50	.12
24-12 Stainless Steel.......	24	12	1.50	1.50	.25
Chromium Iron...........	26	..	1.00	.50	.25

Figure 162. Table of stainless steels

from oxidation by means of a flux or coating on the electrode. A common flux contains ½ pound zinc chloride, ⅓ oz. hydrochloric acid, 16 oz. water, ½ oz. potassium dichromite. Because of the relatively high amounts of the alloy metals, most of which have a high coefficient of expansion, these metals warp and buckle more noticeably than straight carbon steels. An oversize tip with a soft flame may be used to minimize warpage. For this reason arc welding is generally recommended because its speed minimizes the warping tendency. Stainless steel articles, when being welded, must be clamped firmly to some alining fixture to minimize warping. The repairing, by welding, of parts made from these metals is very similar to that to be followed for straight carbon steel. Copper backing plates help prevent warping.

The preparation of the metal for welding is very similar to that used for low, straight-carbon steel. One must be very careful not to oxidize, or overheat stainless steel, as this seriously discolors it and ruins the properties of the metal. One will usually find that after finishing a welding operation the metal is discolored. However, if correctly done, the discoloration will be only on the surface, and a certain amount of grinding and buffing will bring back the original appearance of the metal. Filler rods containing small amounts of columbium are recommended as this prevents intergranular corrosion in the weld.

185. Chromium Steel

Some steels which are corrosion resistant, but still are not classed as stainless steels, contain chromium as their principal alloying metal. One group containing 4% to 6% chromium are corrosion resistant, especially to sulphides, and are also applicable to cold working. The carbon content of these steels varies between .10% to .25%. Welds on these metals should always be annealed as

quickly as possible after welding. Some of these steels occasionally have a little molybdenum, or tungsten, added to increase the strength of the steel especially at the higher temperatures.

186. High-Nickel, Low-Chromium Steels

The high-nickel, low-chromium steels are better known as Inconel or Nickrome steels. These metals contain from 70% to 80% nickel, from 10% to 15% chromium, and the remainder is principally iron.

187. Low Carbon-Molybdenum Steel

In high-pressure, piping work, and in some other welded structures which operate at a high temperature, low-carbon, molybdenum steels are used. The molybdenum content is approximately .5%. It is best to preheat the metal before welding, and anneal it after welding. Otherwise the welding operation is much the same as for mild steel.

188. Review Questions

1. What are two alloy elements used in low-carbon, alloy steels?
2. Why is columbium added to stainless steel filler metal?
3. List three different types of stainless steels.
4. How much iron is contained in high-nickel, low-chromium steel?
5. Why must special precautions be taken to prevent the oxidation of stainless steel during welding?
6. What is the principal advantage of a low-carbon, alloy steel?
7. Explain the trade name U.S.S. 18-8.
8. What two purposes does a copper backing plate serve when one is welding stainless steel?
9. What is the approximate, maximum, carbon content of a low-carbon alloy?
10. Is a low-carbon alloy steel stronger than a straight, carbon steel of the same carbon content? Explain.
11. What is Ascaloy?
12. Why is tungsten sometimes added to a chromium steel?
13. If a stainless steel weld is discolored when one completes the welding, does this mean the weld is worthless in reference to its appearance?
14. Is a stainless steel used solely for its enduring bright finish, or is there another reason for the name "Stainless?"
15. What organization has developed a stainless-steel, standard listing?

CHAPTER XIII

CUTTING

One of the most useful applications of the high-temperature, oxy-acetylene torch and electric arc equipment is for preparing special forms from metal. That is, these high temperatures enable one to shape from standard stock special forms to facilitate the fabrication and assembly of complicated metal structures. Prior to the development of cutting, all large forms had to be cast or built up from standard parts. The casting enabled clean-looking designs, but was laborious; and the strength of the cast metal was naturally limited. The parts fabricated from standard stock and bolted or riveted together were necessarily crude looking, but were much lighter and usually stronger than the cast articles. Cutting and welding enable the industry to fabricate neat looking articles that are extremely strong and very light.

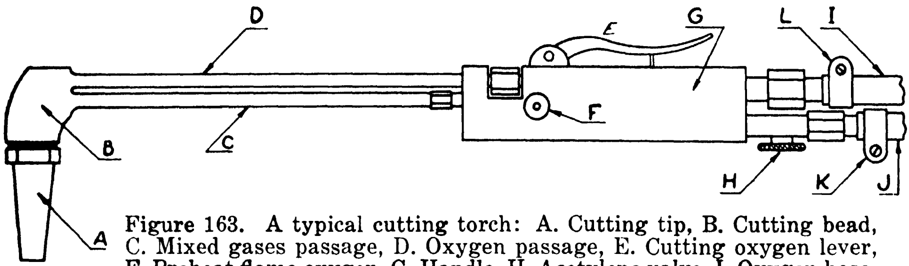


Figure 163. A typical cutting torch: A. Cutting tip, B. Cutting bead, C. Mixed gases passage, D. Oxygen passage, E. Cutting oxygen lever, F. Preheat flame oxygen, G. Handle, H. Acetylene valve, I. Oxygen hose, J. Acetylene hose, K & L. Hose clamps

189. Methods of Cutting

The various methods of cutting metal to special shapes are:

1. The oxy-acetylene cutting torch.
2. The oxygen lance.
3. The carbon arc.

190. The Oxy-Acetylene Cutting Theory

The theory of the oxy-acetylene cutting torch is that when metal is heated to a white heat, or to an abnormally high temperature, oxygen coming into contact with it oxidizes the metal very rapidly. This may be noticed by the fact that after a weld is formed, if it is allowed to remain in the air for just a few hours, a rust colored film forms on its surface. Furthermore, as one welds, a black substance forms adjacent to the weld; this substance is called iron oxide. Therefore, if one were to feed oxygen to a piece of steel

heated to a white hot temperature, the steel would oxidize very rapidly and the oxide formed would be a scaly, brittle, powdery substance. If oxygen were fed to the metal under pressure, the pressure of the gases would blow the oxide away as rapidly as it was formed, leaving a cavity in the metal. If the torch progresses evenly, and at a rate of speed in combination with the speed with which the metal oxidizes, a very clean and straight cut may be obtained in a block of steel. Cutting torches have been used to such proficiency that the finished cut is practically as neat as if the metal were cut with a metal saw.

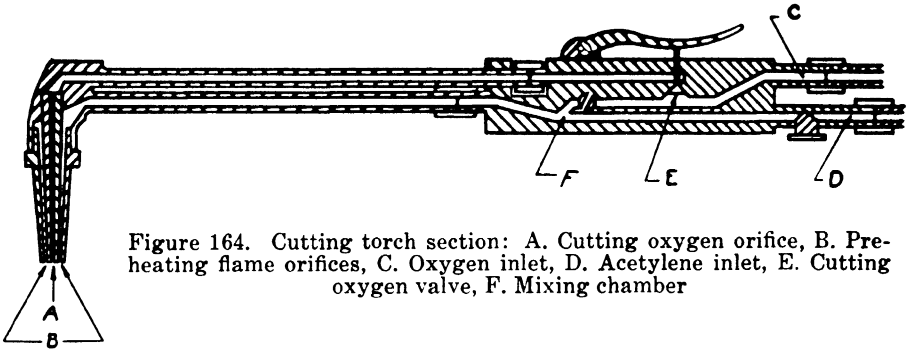


Figure 164. Cutting torch section: A. Cutting oxygen orifice, B. Preheating flame orifices, C. Oxygen inlet, D. Acetylene inlet, E. Cutting oxygen valve, F. Mixing chamber

191. The Oxy-Acetylene Cutting Torch

The oxy-acetylene cutting torch is a typical welding torch with all of the usual welding torch parts; in addition it has a special and separate opening in the tip, out of which the oxygen is forced when the cutting operation begins. The torch itself has two oxygen valves, one for controlling the oxygen to the heating flame, that is, the oxy-acetylene flame; the other valve controls the oxygen jet used for cutting. *Figure 163.* The tip of the torch, therefore, must have at least two openings or orifices, one for the oxy-acetylene flame for preheating, the other one for the oxygen for cutting. However, most of the cutting torch tips have three, four, five, six, and sometimes as high as eight openings for the preheated flame, or flames, while in the center of these openings is a larger opening out of which the oxygen comes to burn the metal. *Figure 164.* Cutting by means of oxy-acetylene is used only on ferrous metals (steel and cast iron.)

192. Oxy-Acetylene Steel Cutting

Of all the metals cut, using the principle of rapid oxidation, the various steels are the easiest to work on. The metals that can be cut may be divided into two classes:

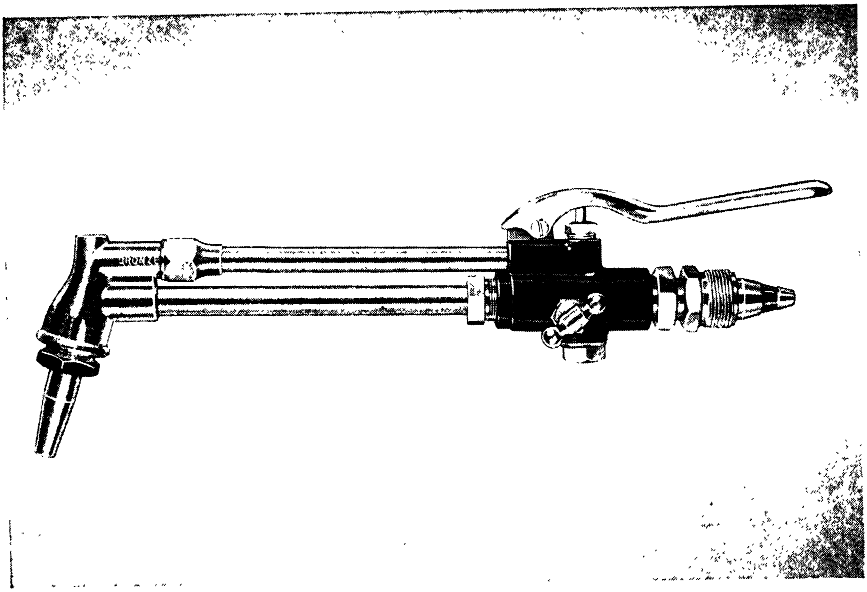


Figure 164A. A cutting attachment for a combination welding and cutting torch
(Courtesy of: Dockson Corporation)

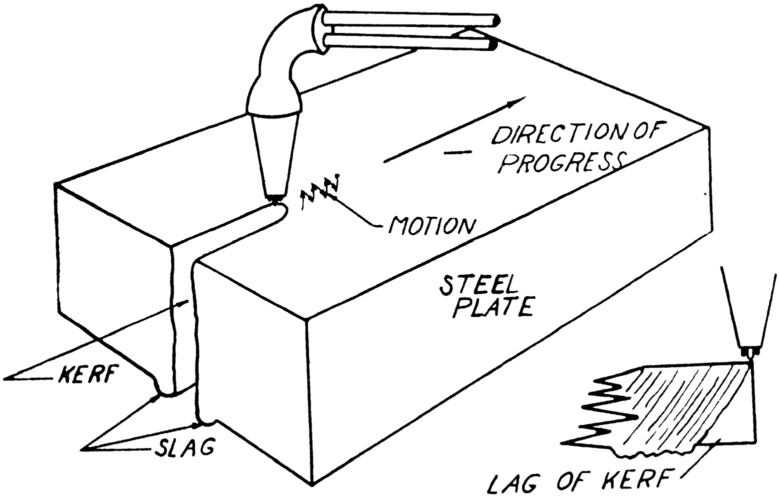


Figure 165. Cutting a thick piece of steel using the oxy-acetylene cutting **torch**

1. That group whose oxides have a lower melting temperature than the metal.
2. That group whose oxides have a higher melting temperature than the original metal.

Practically all steels fall under the first classification and, therefore, their cutting presents little difficulty. When the cutting jet is turned on, the iron oxides, which form, melt before the original metal and are blown away, leaving a very clean and straight cut. *Figure 165.* With an expert handling a cutting torch, or in automatic cutting, the aperture formed by the cut has a smoothness of almost machinelike quality.

The second group, which includes cast iron and some alloy steels, presents a complication because, if the oxide is allowed to solidify, it is almost impossible to remelt and still cut an even kerf. It is very important that the oxides be blown away before they can solidify.

Two things of importance to be watched in cutting are the volume of the oxygen fed to the cut and the speed of the torch motion across the metal. *Figure 166.* If too much oxygen is fed to a metal being cut, the tendency is for the cut to widen as the jet penetrates the thickness of the metal, leaving a bellmouth on the side of the metal away from the torch. *Figure 167.* If the torch is fed too rapidly across the work, the metal on the farther side from the

Metal Thickness	Oxygen Pressure	Acetylene Pressure	Oxygen Cu. Ft./Hr.	Acetylene Cu. Ft./Hr.	Hand Cutting Speed In. Per Min.
1/8	7-20	5	45- 55	7- 9	20 -30
1/4	11-20	5	50- 93	9-11	17 -26
3/8	8-25	5	69-115	10-12	15 -24
1/2	9-25	5	66-125	10-13	14 -22
3/4	20-30	5	117-143	12-14½	13 -20
1	25-35	5	130-160	13-16	11 -18
2	22-50	5	185-230	16-20	7 -13
3	30-50	5	240-290	18-23	6 -10
4	30-55	5	290-390	21-26	5 - 8
5	40-60	5	345-440	24-29	4 - 6.5
6	45-60	5	400-565	26-32	3 - 5.5
8	50-65	6	500-615	30-39	2.6- 4.2
10	50-75	6	600-750	36-45	1.9- 3.4
12	50-80	6	700-875	42-52	1.4- 2.7

Figure 166. Table of cutting pressures and gas consumption for steel using a medium pressure type torch
(Courtesy of: Victor Equipment Company)

torch will be difficult to preheat and will not be burned away. This will lead to a turbulent action of the torch gases and will result in a very rough cut. *Figure 168.* If the torch is moved too slowly across the work, the torch will not preheat the metal sufficiently as

it proceeds, causing the burning action to cease; and the oxygen jet will have to be interrupted until the preheating flames can bring the work up to its proper temperature (bright cherry red) again.

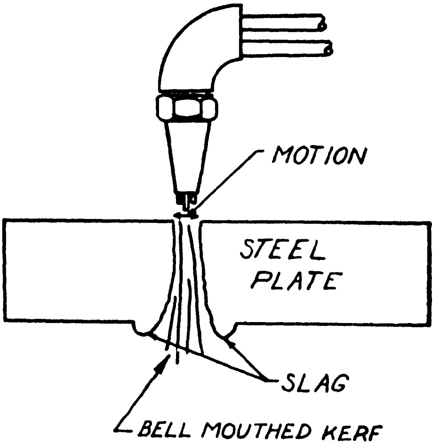


Figure 167. Cutting steel, using too much oxygen pressure

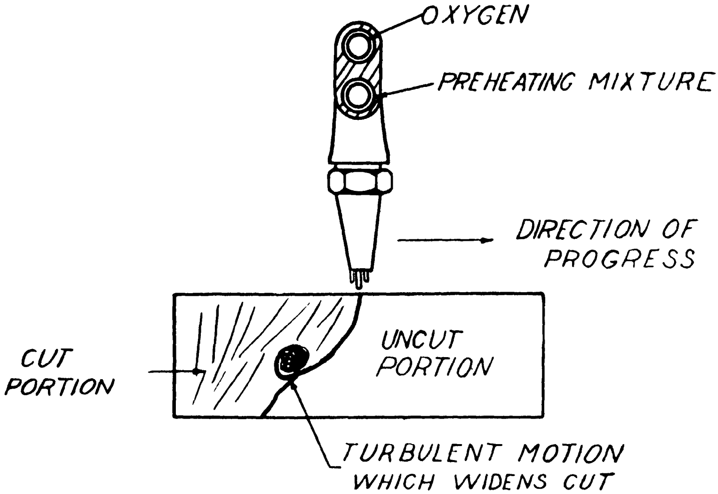


Figure 168. Too rapid a torch speed across the metal

This will also result in an irregular cut. The operator will find it very necessary to clean the surface of dirt and oxides (rust) before starting the cutting operation, as these will slow the cutting speed, making the kerf rough and irregular.

The torch motion to be used is a matter of the operator's own experience. The only general rule to be observed is that the thicker the metal, the wider the cut in the metal (kerf) will have to be. In

some cases the thickness of the metal necessitates an oscillating motion in order to obtain the necessary width of cut. The operator, when cutting, should stand in a comfortable position, and where he can look into the cut as it is being formed. This also means that the torch movement should be away from the operator rather than toward him in order that he may see into the cut aperture. The torch is usually held in both hands. *Figure 169.*

The operator should wear asbestos leggings, and the cuffs of the trousers should be covered to keep them from catching the white hot metal slag as it drops from the cut.

193. Oxy-Acetylene Pipe Cutting

One of the most popular uses of the oxy-acetylene cutting torch is for the fabrication and preparation of pipe, when preparing it

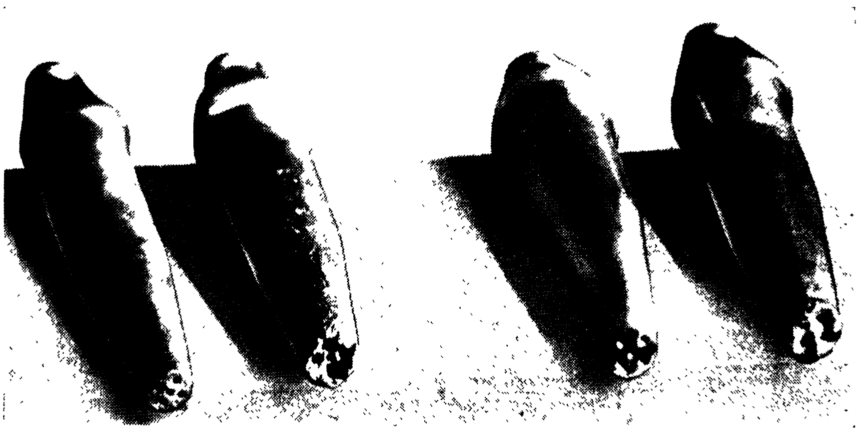


Figure 169. Cutting tips abused and in need of repair
(Courtesy of: Air Reduction Sales Company)

for welding. The cutting torch is especially useful for preparing odd-shaped joints on the job. Also, it may be used extensively to chamfer the edges of thick pipe to provide a "Vee" joint for the welder. The procedure to be followed, when cutting pipe, depends upon the diameter. For small diameter pipe, it is best to keep the torch tip almost tangent to the pipe surface during the complete cutting operation, instead of attempting to cut through the two thicknesses of the pipe simultaneously. With a pipe diameter of approximately four inches and up, it is possible to keep the torch tip perpendicular to the pipe surfaces while cutting, without the torch having a tendency to burn through the other side. Of the

two methods the perpendicular position enables a cleaner and straighter cut. If the welder's helper rotates the pipe as it is being cut, a very clean cut can be obtained.

When chamfering pipe by hand it is best to point the torch toward the pipe, meaning that the flame heats the extreme end of the pipe and blows the metal back along the pipe. This provides a much cleaner chamfer, and it does not leave any excessive oxide clinging to the steel when the weld is completed. It also permits more accurate cutting. Cutting machines, however, reverse this process.

Figure 170. Chamfering pipe with a cutting torch
(Courtesy of: Air Reduction Sales Company)

Figure 170. It must be remembered that when cutting pipe, it is not the size of the pipe that determines the size of the cutting torch tip, but rather the thickness of the pipe wall is the controlling factor. The use of the cutting torch to chamfer pipe, which is to be used for certain high-pressure piping, is not permitted because of the possibility of the oxide coating interfering with the perfect fusion necessary to withstand the high pressure.

194. Oxy-Acetylene Cast Iron Cutting

As mentioned previously, it is more difficult to cut cast iron than steel because the iron oxides of cast iron melt at a higher tempera-

ture than the cast iron itself. However, very successful cutting has been performed on cast iron in salvage shops and in foundries. The most important thing, when cutting cast iron, is to preheat the whole casting before the cutting is started. However, the metal should not be heated to a temperature that is too high, as this will oxidize the surface and make cutting very difficult. When cutting cast iron, the preheating flame of the torch should be adjusted to a carbonizing flame to prevent any oxidation forming on the surface before the cutting starts. The cast iron kerf is always wider than a steel cut because of the oxidation difficulties. After the cutting has been completed, it is very important with cast iron to cool the metal very slowly.

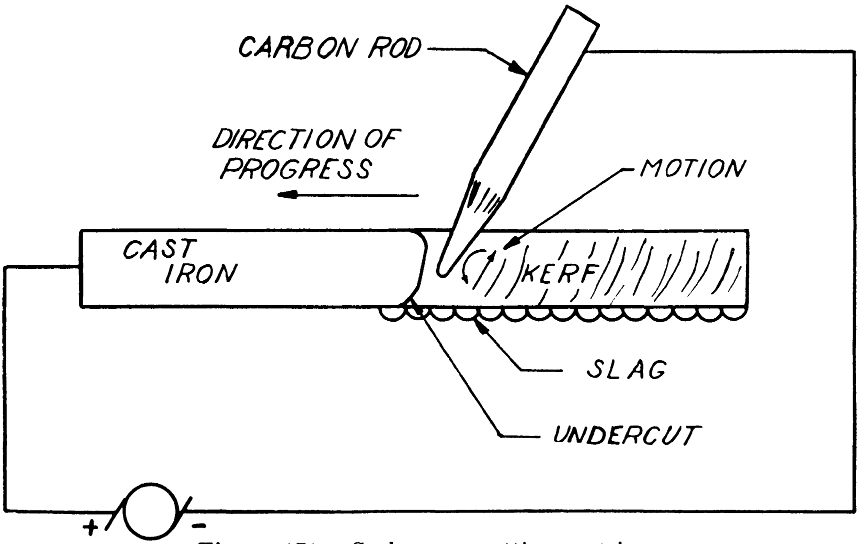


Figure 171. Carbon arc cutting cast iron

195. Carbon and Steel Electrode Arc Cutting

Metals may be successfully cut by using the principle of the electric arc. Small articles can be cut quite successfully by using a mild, steel electrode, if the amperage setting of the machine is set 25 to 50 amperes higher than it would be for arc welding this metal. Another method of electric arc cutting is to use a carbon electrode. The addition of any metal during the cutting process is thereby eliminated. The cutting current should be 25 to 50 amperes above the welding current for the same thickness of metal. The carbon rod should be ground to a very sharp point. During the actual cutting, the carbon rod should be manipulated in an elliptical movement to undercut the work, which facilitates the removal of the

slag. As in oxy-acetylene cutting, a crescent motion is recommended. *Figure 171.*

The carbon arc method of cutting has been used very successfully on cast iron because the temperature of the arc is sufficient to melt quite easily the oxides formed. It is especially important to undercut the cast-iron "kerf" if one desires an even cut. *Figure 172.*

196. Cutting Holes (and Piercing)

Holes may be pierced in steel plates very rapidly and with quite accurate results. To pierce a small hole through a steel plate, the process consists of holding the cutting torch with the nozzle perpendicular to the surface of the metal, and preheating the spot to be cut until it is a bright, cherry red. After the metal is brought

Cutting Speed in Minutes Per Foot

Thickness of Plate Inches	Welding Current			
	300 Amps.	500 Amps.	700 Amps.	1000 Amps.
½	3.5	2.0	1.5	1.0
¾	4.7	3.0	2.0	1.4
1	6.8	4.1	2.9	2.0
1¼	9.8	5.6	4.0	2.9
1½	...	8.0	5.8	4.0
1¾	...	...	8.0	5.3
2	...	...	...	7.0

Figure 172. Carbon cutting speeds
(Courtesy of: National Carbon Company, Inc.)

up to the proper temperature, the oxygen jet may be turned on very slowly. At the same time, the nozzle should be raised enough to eliminate the slag being blown back into the nozzle orifice. Because of the great amount of heat required in an operation of this kind, it is recommended that the operator use the next larger tip in relation to the thickness of the metal, as recommended in *Figure 166.*

To cut larger holes in steel plate, a process exactly similar to the typical, steel-cutting method is recommended. It is good practice, however, to outline the hole first, using special chalk in order that this line may be used as a guide to permit the operator to cut as accurate a hole as possible. If the size of the hole warrants it, it is best to do the cutting with an automatic machine, or a radius bar attachment which may be clamped to the torch head.

197. Rivet Cutting and Gouging

The cutting torch, in salvage operations, is frequently used for removing rivet heads in order to dismantle large fabricated structures. Two typical rivet shapes cover the field quite thoroughly. These are:

1. The button head rivet
2. Countersunk rivet

The procedure for cutting these heads is fundamentally the same as for any cutting operation, but one additional precaution should be observed. If possible, the operator should do the cutting with-

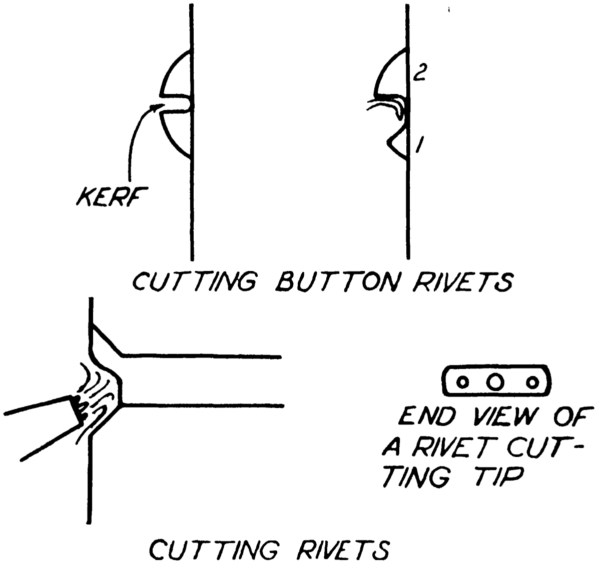


Figure 173. Cutting rivets

out damaging the steel plate. To do this it is very important that the size of the tip should be carefully selected. If too large a tip is used, the steel plate will be injured at the same time the rivet head is being removed. If too small a tip is used, the method becomes too slow. Practically all welding equipment companies recommend special cutting nozzles for rivet cutting. *Figure 173.*

The procedure for cutting the button head rivet is to preheat the head of the rivet to a bright cherry red, the body of the steel plate usually being adequately protected from this preheating by the coating of scale on it. The rivet is then cut diametrically through its thickness. Then one-half the head is removed, preferably the lower half, and finally the upper half. The appearance of an accurately performed job shows a clean removal of the head without any score marks from the cutting jet on the steel plate.

The removal of a countersunk rivet head is more difficult than the above because of the fact that the rivet is tightly embedded in the steel plate. However, by carefully selecting the tip size, and by proceeding with the cutting from the bottom of the rivet head upward, after the head has been preheated, these countersunk rivet heads may be removed with very little damage to the original steel plate.

Cutting a curved chamfer on the edge of a plate or removing a bad spot in a weld to prepare it for rewelding are other popular uses for the cutting torch. In an automatic machine a gouging tip will do very accurate cutting while the bevel operation of the gouging tip to remove bad spots is a very quick and convenient method of preparing metal for welding.

198. Cutting Alloy Ferrous Metals

The introduction of many alloy steels into industry has made it necessary for new cutting techniques to be developed in order that these steels may be successfully and economically cut. Of these alloy steels, stainless steel is perhaps the most widely used. The additional materials which comprise stainless steel are chromium and nickel. These metals have a melting temperature below that of steel. They, therefore, offer somewhat the same difficulty as cast iron when being cut. The oxides formed, having a melting temperature higher than the original metal, must be removed from the cut immediately, or they will stop the cutting action. It has been found that for the same relative thickness of metal, stainless steels need approximately 20% more preheating flame and 20% more oxygen for the cutting. It has also been found that it is a good practice to use a slightly carbonizing flame when preheating.

The metal to be cut should be so placed that the cutting plane is in a horizontal position. The cut should start at the top and proceed downward in a vertical line. A slight, but quick, up-and-down motion of the torch facilitates the removal of the slag. It will be found impossible to obtain as clean and narrow a kerf when cutting alloy metals as when cutting straight carbon steels. *Figure 174.*

As in the case of steel and cast iron, the alloy metals must be preheated before the cutting operation is started. The stainless steels especially, must be preheated to a white heat in order that the cutting may be successful. The cutting action is much more violent with stainless steels than with straight carbon steels, with considerable sparking and blowing of the slag taking place.

In those situations where the progress of the cutting is frequently

interrupted by the presence of unmeltable slag, the cutting operator will find it convenient to hold a mild steel filler rod in the kerf of the metal. This mild steel, upon being melted by the cutting torch, has the power to absorb the slag from the other metal, enabling the cutting to proceed more smoothly. This method of adding filler rod to the cut is especially applicable to poor grade, cast iron casting and to old, oxidized, steel castings.

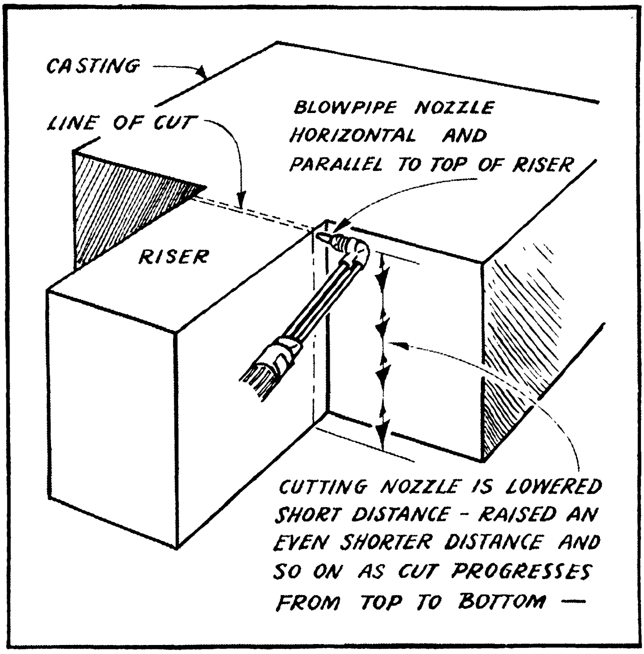


Figure 174. Oxy-acetylene cutting chromium steels
(Courtesy of: Linde Air Products Company)

199. The Oxygen Lance

A method of cutting which is used extensively on thick metal is the "oxygen lance." This apparatus, which is patented, enables one to cut metal up to five or six feet in thickness. The apparatus consists of an oxygen cylinder, a rubber hose, an oxygen pressure regulator, and a length of one-eighth or one-quarter inch pipe. *Figure 175.* When the lance is used for large size cutting, several oxygen cylinders are manifolded to provide sufficient oxygen.

The principle of operation of this lance is identical to that of the cutting torch with some modifications. First, the preheating flame is not included in the lance, but is separate; oxy-acetylene or other gas torches are used.

As the pipe extends down into the cut, the pipe is also subjected to excessive temperature in the presence of oxygen, and the end of the pipe is also burned away. However, the end of the cutting lance has been known to pierce the center of a freight car axle shaft through its length without burning through the side of the shaft. Considerable expense is eliminated, when cutting large steel or cast iron sections, by using this method.

Figure 175. The oxygen lance in operation
(Courtesy of: Linde Air Products Company)

It is used extensively for cutting the risers off large castings, in salvage operations, and for opening the pouring gates in large furnaces.

200. Special Applications of Cutting

The cutting torch has several special uses that are worthy of mention. A special cutting torch is available for under water cut-

ting. Down to a 25 foot depth oxy-acetylene flame is used. Below this depth the acetylene pressure becomes dangerous. However, the oxy-hydrogen flame has been used to a depth of 200 feet. The torch has a special high pressure air connection, the purpose of which is to keep the water away and maintain an air pocket at the point of cutting. Special training is required and the operator must be a competent diver for safety. *Figure 176.*

Regular cutting torches are sometimes equipped with special tips that are bent out of line and are used for gouging grooves in metal. This grooving tip is used to make special chamfers in metal edges when preparing metal for welding and to remove bad spots in welds so these spots may be welded again.

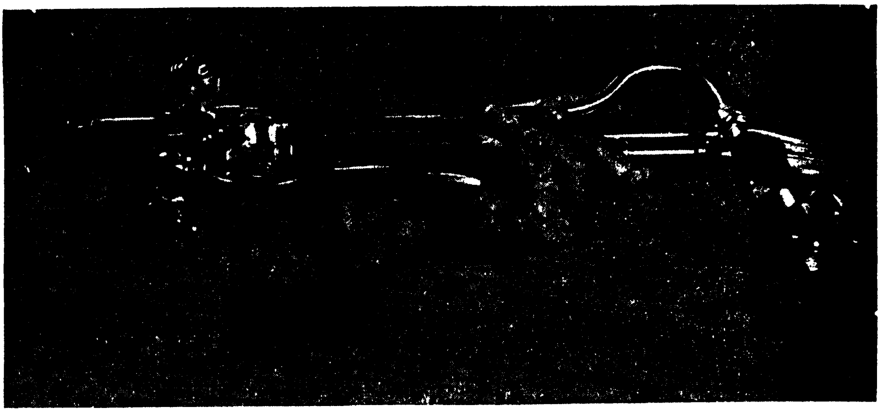


Figure 176. Underwater cutting torch
(Courtesy of: Victor Equipment Company)

201. Automatic Cutting

There are many automatic mechanisms available, which perform automatic cutting operations, using the oxy-acetylene cutting torch. Some are used for cutting definite numbers of certain shaped objects; some are used for cutting a number of the same sized objects simultaneously; some are used to cut irregular shaped articles, using some inexpensive template as a guide; while some are used to cut straight kerfs and to chamfer metal.

Practically all of these automatic cutting torches are driven by means of variable speed electric motors. Those used in production of duplicated articles by the thousands are usually cam-actuated, while those used to reproduce a certain number of the same sized articles simultaneously use multiple torches. *Figure 177.*

The most popular type of automatic cutting machine is the type

which follows the contour of a wooden or aluminum pattern, and cuts a duplicate shape in the metal. The variable-speed, electric motor permits various speeds in feet per minute. This is to adapt

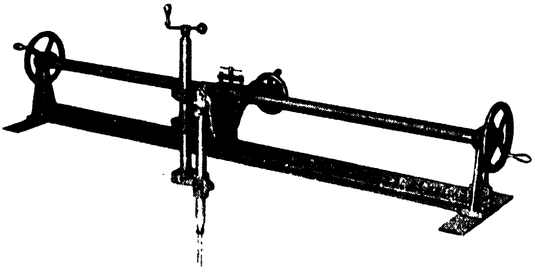


Figure 177. An automatic oxy-acetylene cutting machine
(Courtesy of: Victor Equipment Company)

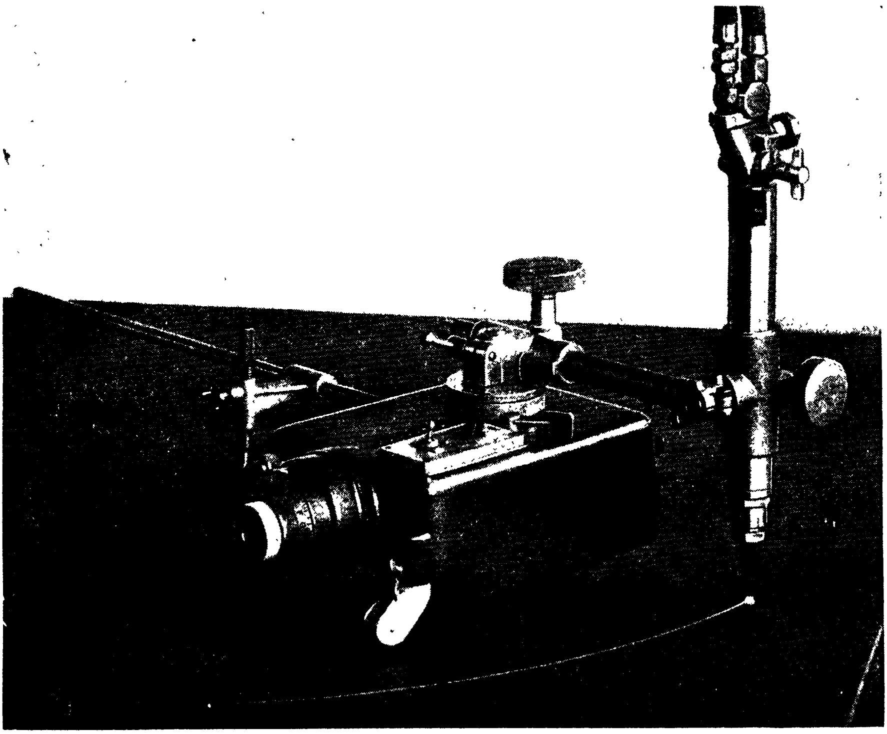


Figure 178. An oxy-acetylene cutting machine for irregular curves
(Courtesy of: Air Reduction Sales Company)

the machine to different thicknesses of metal. *Figure 178.* The guide for the torch is a small rail which has been shaped to conform with the wood or metal pattern; and the machine has a specially calibrated tachometer, which registers in feet per minute.

The operation of these automatic machines necessitates three important adjustments:

1. The adjustment for the rapidity of the cut, which is easily controlled by the speed of the motor or a gear train.
2. The gas pressures must be carefully adjusted to procure a clean cut through the thickness of the metal without wasting the gases.
3. The distance of the torch tip from the metal being cut must be carefully adjusted to obtain the best results. This is done by means of a graduated scale on the torch body, and a gear vernier mechanism to raise and lower the torch.

Once set up, the apparatus is self-operating. However, the initial adjustments must be very carefully made.

202. Review Questions

1. What metals may be cut with the oxygen-acetylene cutting torch?
2. May electric current be used for cutting metals?
3. Describe the construction of the oxy-acetylene cutting tip?
4. What happens to the kerf in steel when too much oxygen is used?
5. May pipe be beveled with an oxy-acetylene cutting torch?
6. What is used to drive an automatic cutting machine?
7. Why must cast iron be specially preheated before cutting?
8. Of what is an oxygen lance made?
9. What oxygen pressure should be used for cutting 3″ thick, steel plate?
10. To what temperature should steel be heated before the oxygen jet is opened?
11. Is a torch motion necessary when cutting steel?
12. What will happen if the torch is moved forward too rapidly?
13. What is the name of the slot formed by the cutting torch?
14. Should one protect his feet when cutting?
15. How is the metal preheated when an oxygen lance is used?
16. Why is cast iron "undercut"?
17. What is the type of preheating flame used when cutting cast iron?
18. Why isn't torch cutting and chamfering of high-pressure pipe recommended?
19. What special device is recommended for cutting button rivets?

CHAPTER XIV

SPECIAL FORMS OF WELDING

Welding is usually defined as the fusion of metals. This general classification, therefore, includes all methods that have been developed for fusing metals together. Some of these methods are highly specialized in their application. Some are patented, and these may be used only with the permission of the patent owners, while others are special developments of oxy-acetylene welding and arc welding. Some of these special forms of welding are thermit welding, metal spraying, atomic-hydrogen welding, the hydrogen furnace, and the blacksmith's forge welding.

203 Thermit Welding

Thermit welding is based upon the fundamental chemical knowledge that aluminum is a more active metal than iron. The process consists of mixing iron oxide and aluminum in a powder form, and then bringing this mixture to a temperature of 2,000 to 2,500 degrees Fahrenheit. The aluminum will then combine vigorously with the oxygen in the iron, producing a temperature of approximately 5,000 degrees Fahrenheit. This forms an aluminum slag and pure liquid iron at a temperature considerably above its melting temperature. When this high-temperature, molten iron is permitted to come into contact with a specimen of steel, it will melt the surface of the steel and will fuse with it. One can readily see that this method may very conveniently be used to weld iron to steel. It is very popular where large sections are to be welded together and where preheating is inconvenient because of the size of the pieces to be welded.

Thermit welding may be roughly compared to casting, with the one difference that the metal being poured is of a considerably higher temperature than metal melted in a furnace. Common applications of Thermit welding are to weld railroad rails together, to weld new teeth on large gears, to weld large fractured crank shafts, to weld together sections of castings whose size prevents their being cast in one piece, to repair large steel structures that are made only on special order and would be very costly to replace. Thermit welding has been applied successfully to every industry. Thermit welding is also used for welding pipe, where the Thermit

does not mix with the pipe metal, but merely furnishes the heat to melt the pipe ends, which are then butted together as they melt.

204. Procedure for Thermit Welding

Inasmuch as Thermit welding is a specialized form of casting, molds are necessary to control the flow of the liquid iron, and to shape it while it is in a liquid form. The metal to be welded is firmly and accurately set up to be welded after the fracture has been pre-

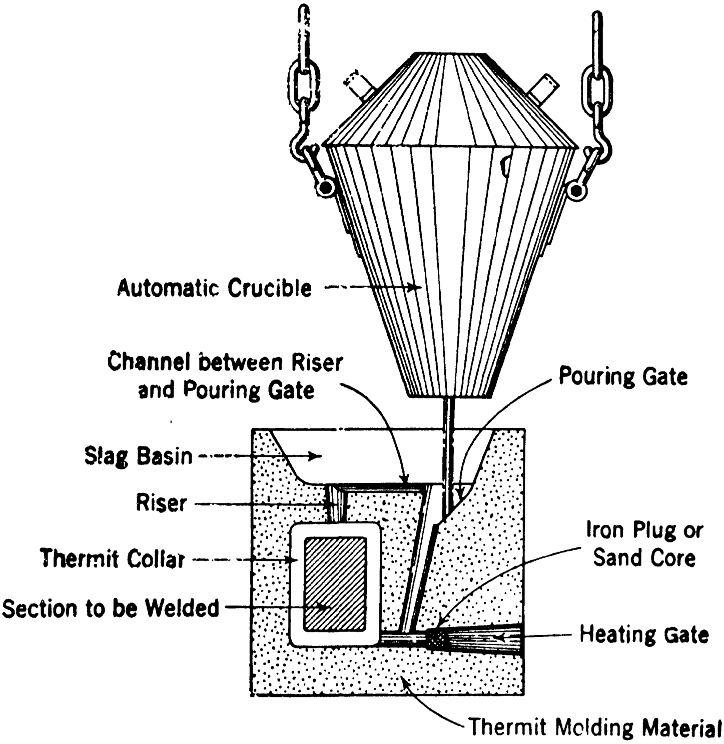


Figure 179. A complete thermit assembly showing the crucible and the mold
(Courtesy of: Metal and Thermit Corporation)

pared. In preparing the fracture, the joint is usually machined to provide a "V" gap all around the fracture of the joint to enable the molten metal to gain access to all parts. A wax pattern is then placed in this fracture and built up to the form that the molten metal is to take as it pours into the joint. A sand mold is then built around the wax pattern and the work to be welded. Pouring gates and risers must be provided in this mold just as in regular molding while vent holes are necessary on the larger jobs. During the pre-heating of the metal to be welded, the wax used as a pattern burns

away, leaving the correctly shaped cavity to receive the self-heating metal. *Figure 179.*

A large, funnel-shaped container, constructed of the same materials as the mold, is built above the mold. This funnel contains the aluminum and the iron oxide in their original powder form in sufficient quantity to provide enough iron for the weld. *Figure 180.* The usual procedure is to place this mixture above the weld in order to allow the highly super-heated iron to flow into the weld by gravity through the pouring gate.

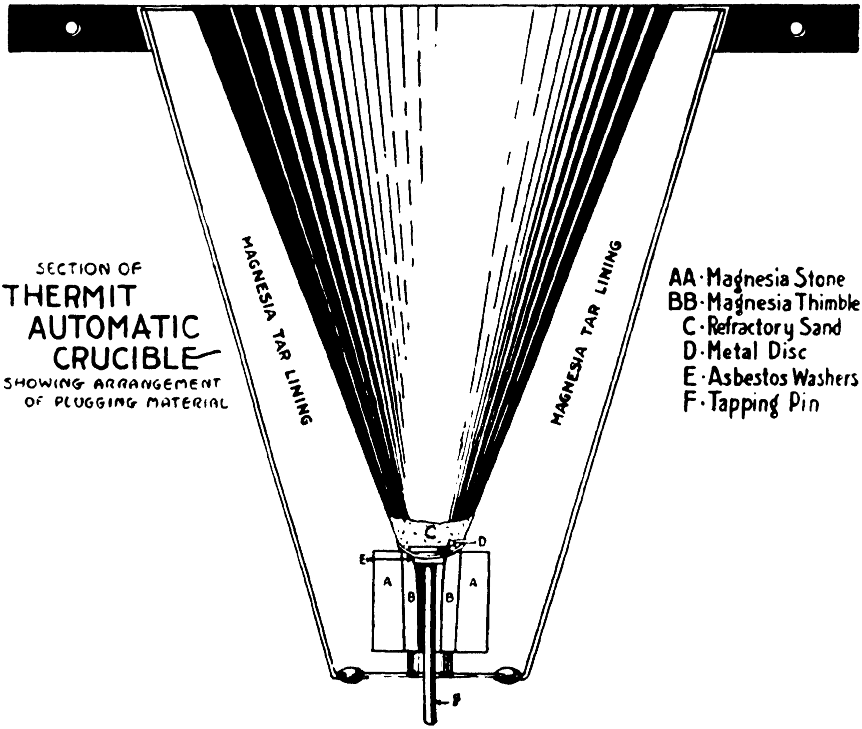


Figure 180. A thermit weld crucible: AA. Magnesia stone, BB. Magnesia thimble, C. Refractory sand, D. Metal disc, E. Asbestos washers, F. Tapping pin
(Courtesy of: Metal and Thermit Corporation)

One special construction that the Thermit mold must have, which is different from the regular molds used in casting, is the preheating gate, which provides for preheating the metal just prior to the pouring of the iron. An ignition powder, a special powder which burns at a high temperature, must be used in order to start the ignition of the Thermit mixture. The aluminum and iron oxide mixture, as mentioned previously, will ignite only after it has reached the temperature of approximately 2,000 degrees Fahrenheit. Once

the mixture starts to burn, it is self-propagating. The chemical action should be allowed to go to completion before the pouring is started.

The process is considered very safe because of the very high temperature necessary to ignite the Thermit mixture. This eliminates any chance of accidental ignition of the mixture at any time. After the weld is completed and the metal has been allowed to cool down slowly, the mold is removed and the weld is cleaned. *Figure 181.*

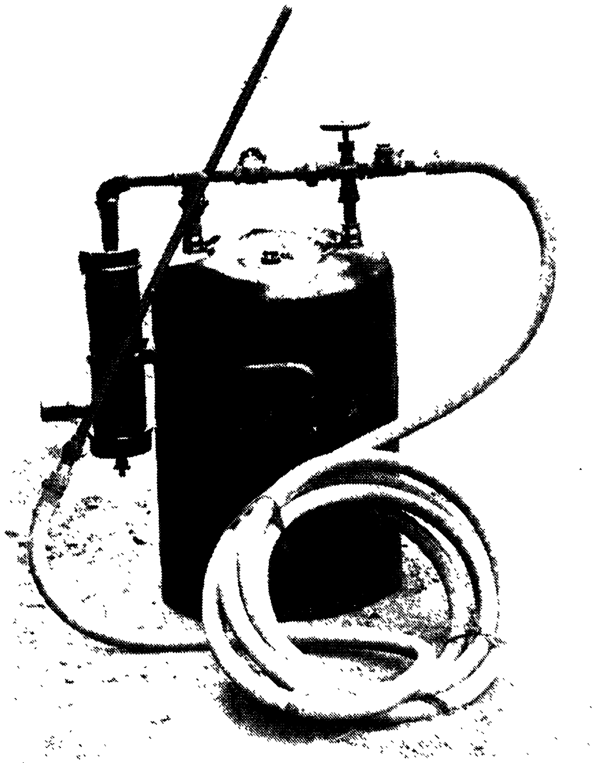


Figure 181. A preheater torch for thermit welding
(Courtesy of: Metal and Thermit Corporation)

After the removal of the mold, the weld needs considerable trimming because of the excess metal clinging to the weld, such as the pouring gate metal, the riser metal, and the metal in the vent holes. *Figure 182.* In case several similar pieces are to be welded, special two-piece, clay molds may be made, enabling the same mold to be used more than once, and eliminating the need of forming a pattern of the weld with wax.

The molding sand used in Thermit welding is usually of a special mixture of silica sand and plastic clay. The pouring gate is closed with a metal poppet valve, covered with a thin sheet of asbestos, which in turn is covered with a very thin coating of silica. Before applying the mold to the work to be welded, it is necessary to clean the fracture until the entire surface is bright, and also to clean the metal as far back along the specimens as it is to be covered by the molding sand. It is especially important to remove any oil, grease, or water from the metal being welded as this would cause the mold to burst.

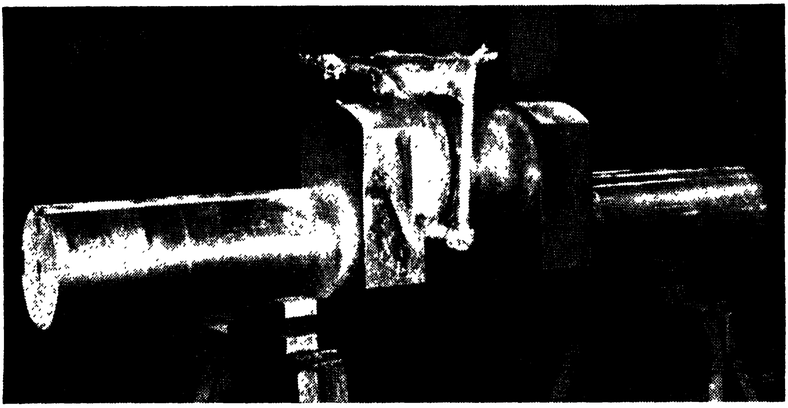


Figure 182. A thermit repaired crankshaft. Note the risers
(Courtesy of: Metal and Thermit Corporation)

205. Metal Spraying

A newly developed branch of welding is the art of building up a metal surface by applying molten metal in a vapor form to the surface to be coated. It may be used to advantage for building up worn surfaces, for reclaiming under-sized parts, and for coating a sur-

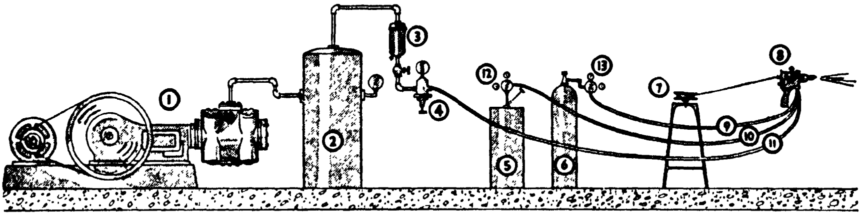


Figure 183. A complete metal spraying outfit: *1* Air compressor; *2* Air receiver; *3* Moisture filter; *4* Air pressure regulator; *5* Acetylene tank; *6* Oxygen tank; *7* Wire reel; *8* Metallizer; *9* Oxygen hose; *10* Acetylene hose; *11* Air hose; *12* Acetylene pressure regulator; *13* Oxygen pressure regulator; *14* Adequate sand blast equipment
(Courtesy of: Metallizing Co. of America, Inc.)

face with any number of different kinds of metals. The latter use is for protection and for decorative work. *Figure 183.*

The theory of operation is as follows: a wire made of the metal to be sprayed is fed into a melting chamber just ahead of the welding flame. The flame melts the wire, and the pressure of the air sprays this metal in a molten form upon the surface. The wire is fed to the flame automatically in order to provide a steady stream of metal vapor. A small air motor is used to feed this wire into the welding torch at a constant rate. *Figure 184.* A list of the metals that may be sprayed without difficulty is as follows:

a. Lead and lead alloys
b. Zinc and zinc alloys
c. Copper
d. Tin
e. Brass
f. Cadmium
g. Nickel
h. Silver
i. Aluminum
j. Monel metal
k. Phosphor bronze

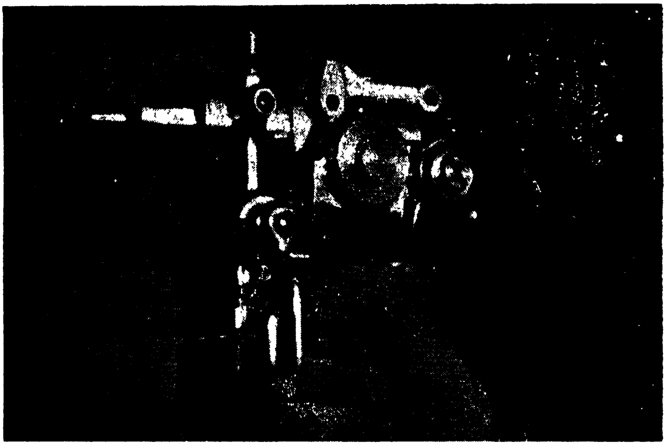


Figure 184. A metal spraying torch
(Courtesy of: Metallizing Co of America, Inc.)

206. Metal Spraying Procedure

The material to be metal-sprayed must be very carefully cleaned; preferably the surface should be roughened by sand blasting. It is absolutely essential that the surface should contain no foreign matter. To clean articles by sand blasting, the article is mounted in a specially built booth, provided with large exhaust fans. The operator must wear gloves, and he must wear a special mask for breathing while the operation is proceeding. The air used in the sand blast gun should be dry and free from oil. A special cleaner and drier should be placed in the air line for this purpose. Sand

blasting is required where any surfaces are to metal sprayed. *Figure 185.* On large articles, especially in close quarters, it is necessary that the operator use a mask while spraying. However, normal usage does not warrant this precaution.

The success of spraying depends considerably upon the adjustment of the metal spraying torch. These adjustments are:

1. The amounts of gas fed to the flame
2. The rate of speed of the wire being fed to the chamber
3. The distance the torch is held from the surface being sprayed; this quality has the greatest effect upon the quality of the finished product.

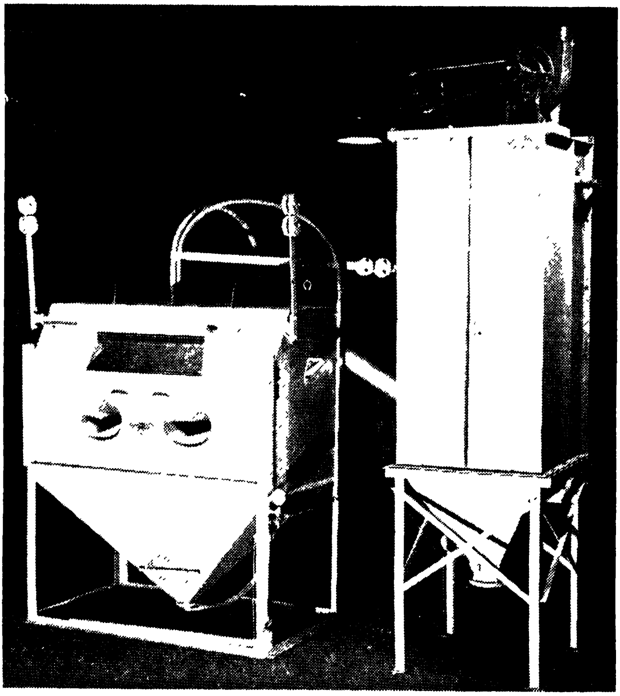


Figure 185. Sand blasting equipment
(Courtesy of: Ruemelin Mfg. Company)

Under microscopic and chemical tests, the surface is found to be rough, and the metallic oxide content is higher than for a cast or rolled metal. However, the metal is of sufficient durability that crank shafts of all kinds and other wearing surfaces have been built up by this method, and have stood service almost as well as the original surface.

The metal spraying torch uses approximately 15 pounds per square inch acetylene pressure; it uses oxygen pressure sufficient to

neutralize the flame (about 15 lbs. per sq. in.), and air pressure of about 60 to 70 lbs. per sq. in. These pressures are applicable to the Metallizer 3 in. and 1 torch which uses a No. 15 B. & S. gauge wire. The larger model "Mogul" is used to obtain greater speeds. This torch requires 25 lbs. per sq. in. pressure of acetylene, approximately 27 lbs. per sq. in. pressure of oxygen, and 75 to 85 lbs. per sq. in. pressure of air.

This latter torch consumes approximately 45 cubic feet per hour of acetylene, 52 cubic feet per hour of oxygen, and 45 cubic feet per minute of air. The machine uses No. 11 gauge B. & S. gauge wire.

The method of computing the cost for metal spraying is based on the square foot of flat surface sprayed, and upon the square inch cylindrical surface sprayed. The surfaces are usually built up to an approximate thickness of .015″. However, if the surface is to be polished, or if it is to be rethreaded, the metal may be sprayed to a thickness of .030″.

For flat surfaces the metal is figured to be deposited at 100% efficiency, while for round surfaces the efficiency of spraying decreases as the diameter decreases. For example, the amount of metal deposited on a three inch shaft is only 75% of the amount sprayed from the torch. The amount of metal sprayed per hour by the average torch varies with the kind of metal. For example, stainless steel may be applied at the rate of 2.4 pounds per hour while bronze may be applied at the higher rate of 4.7 pounds per hour.

207. Atomic-Hydrogen Welding

A unique method of welding, which really combines gas welding with electric arc welding, is the atomic-hydrogen process. A special electrode holder is constructed having two electrodes and a hydrogen outlet. An electrical arc is passed between the two electrodes at the same time that a stream of hydrogen gas is ejected from the hydrogen nozzle, between these two electrodes. The electric arc breaks down the molecular hydrogen into atomic-hydrogen. The atomic-hydrogen stream then contacts or impinges upon the metal to be welded. Touching the relatively cold metal, the atomic-hydrogen recombines into molecular hydrogen, liberating considerable heat. This heat melts the metals to be welded.

The method has two outstanding advantages:

1. The arc and, therefore, the amount of heat liberated are consistent at all times, regardless of the work being welded.
2. The hydrogen provides a reducing gas atmosphere under which the fusion takes place. This eliminates any oxidation

(burning) of the weld metal, producing greater density and more ductility.

The arc welding machine proper is of the A.C. type, and the operator uses a filler rod to supply any additional metal needed.

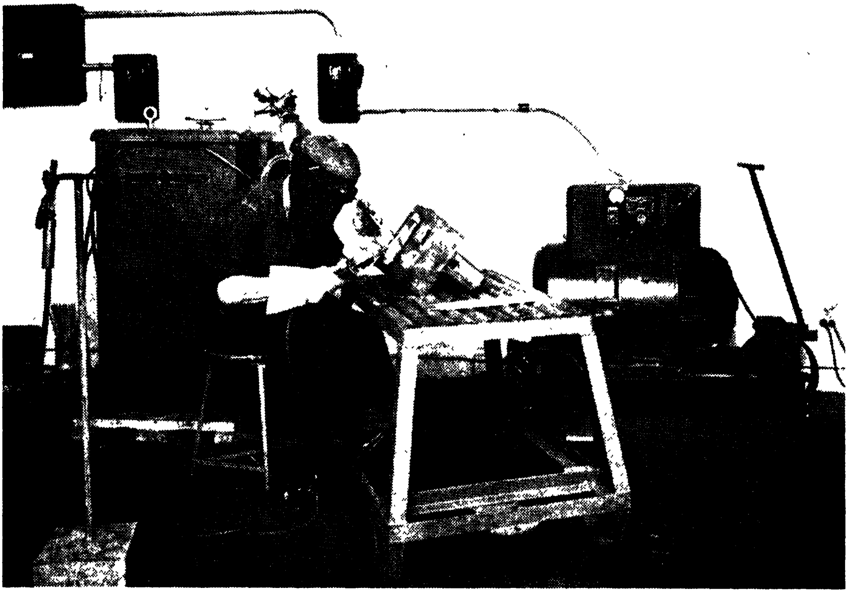


Figure 186. Atomic-hydrogen apparatus
(Courtesy of: General Electric Company)

208. Atomic-Hydrogen Welding Apparatus

Equipment used in the atomic-hydrogen welding may be divided into three sections, the electrical and gas supply, the electrode holder, and the operator's equipment. The electrical supply is usually alternating current and is transformed from the higher voltage down to a voltage considered safe to be handled by the operator. The transformer used for this purpose is usually a constant potential type; that is the voltage used at the holder is kept constant. The amperage is varied by means of a hand wheel adjustment, mounted on the transformer body. The transformer proper is usually air cooled. *Figure 186.* The hydrogen is furnished in two hundred cubic feet cylinders under a pressure 1,800 lbs./sq. in. A regulator is used to reduce this pressure to two or three lbs./sq. in. at the electrode holder. The electrode holder is equipped with two tungsten electrodes with their ends forming a gap just beyond the hydrogen orifice. *Figure 187.* The operator's equipment is standard and similar to that which the usual arc welder uses.

209. Controlled Atmosphere Furnace

A new method of fabricating articles, and one that has become very popular in the last few years for the fabrication of small articles, is the controlled atmosphere brazing furnace. The method originated in 1907, but only recently has it become very popular. It consists of a typical furnace, usually heated on the inside by electrical resistance coils or partly combusted fuel gases. The inside of the furnace is usually kept as nearly gas-tight as possible, and little air is allowed to enter into it. Instead, the only gas fed into the furnace is a very low mixture of air and fuel gas. *Figure 188.* A suffi-

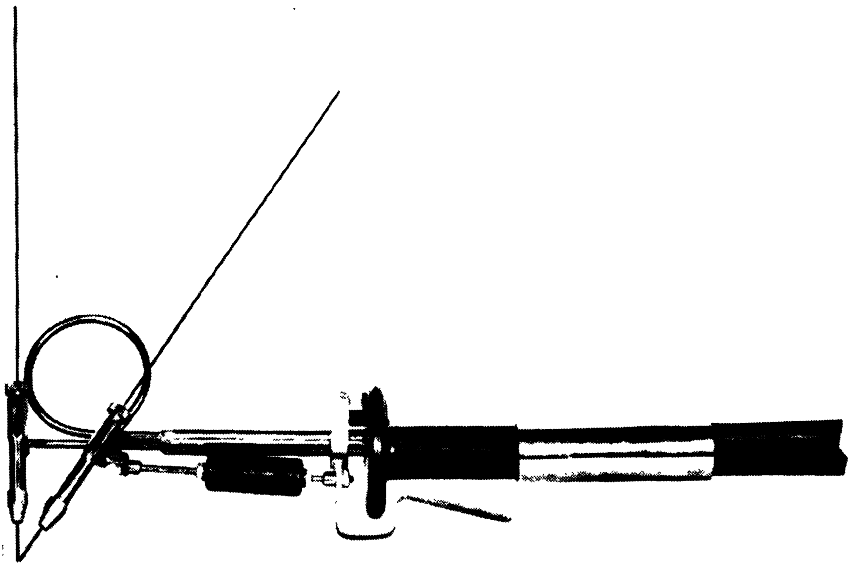


Figure 187. Atomic-hydrogen electrode holder
(Courtesy of: General Electric Company)

cient temperature is maintained inside the furnace to melt copper, brass, bronze, and silver alloys without melting the more common iron and steel metals. Recent developments in aluminum alloys enables the brazing of aluminum and its alloys in the reducing atmosphere furnace. The operation of the furnace is as follows:

If two articles such as the two ends of a small steel cylinder are to be fastened together, they are first cleaned and then assembled in their final form. A small wire of the alloy, which is used to join them, is placed inside the furnace; upon being subjected to the high temperature in the reducing atmosphere, the wire melts and joins the two surfaces together very tightly. The article is then removed

Figure 188. Controlled atmosphere furnace for production welding and brazing
(Courtesy of: Continental Industrial Engineers)

from the furnace and cooled slowly in a neutral atmosphere; when finished, the joint is approximately as strong as a weld would be, and the product is completely assembled while the hard soldering process is being performed. The method is very well adapted to production work, for it insures a very high quality joint, and simultaneously cleans the complete article, eliminating one manufacturing step. The reducing atmosphere of partly burned fuel gases eliminates any oxidation of the metals.

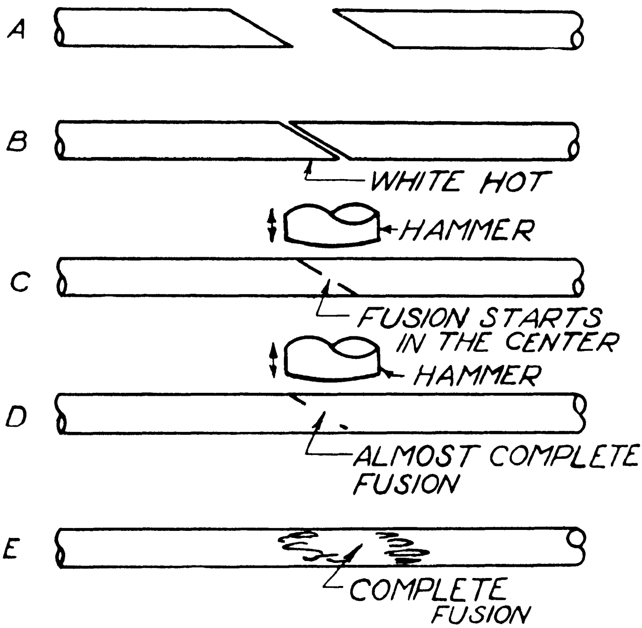


Figure 189. A diagrammatic illustration of the steps in blacksmith welding

210. Blacksmith Welding

The oldest form of fusing two pieces of metal together is called blacksmith welding. This type of welding requires considerable skill on the part of the operator, and is limited to the joining of solid steel stock together. The ends of the two pieces of metal to be welded together are placed in a blacksmith forge, which uses a banked fire of charcoal or coal with an air blast, used to produce the higher temperatures necessary. The ends of the metal are heated to a white heat just short of the rapid oxidizing or burning point, and are then placed together so that the surfaces may be forced one against the other suddenly by the impact of a hammer. A blacksmith usually tapers the ends to be joined. The pressure of the

hammer blows, and the extra heat produced from the hammering, fuse the two pieces together. *Figure 189.* The energy from the shock of the hammer blows forces the oxide from between the surfaces of the metals, and raises the temperature of the contact surfaces high enough to enable them to fuse.

A weld of this nature when done correctly has every quality of the original metal. However, because of the skill necessary to produce a successful joint, and the relative ease with which other processes accomplish the same task, this type of welding is slowly being replaced by modern welding processes.

211. Review Questions

1. What are the two metals used in the Thermit welding mixture?
2. What kinds of metals are best welded with this process?
3. What is the purpose of the riser on a Thermit-weld mold?
4. How many gases are used in the metal spraying torch?
5. What is the compressed air used for in the metal spraying torch?
6. May stone surfaces be metal sprayed?
7. In what form is the metal fed to the metal-spraying torch?
8. Where does the heat come from originally which is used to melt the parent metal in the atomic-hydrogen welding process?
9. Why can't open gas flames be used inside a hydrogen atmosphere furnace?
10. What kind of metal may be blacksmith-welded?
11. What is sand blasting?
12. Why is sand blasting a surface recommended prior to metal spraying?
13. May steel pipe be Thermit welded?
14. Of what materials are the atomic-hydrogen electrodes made?
15. What is the grit used in sand-blasting?
16. How is the air treated when it is to be used for sand blasting? Why?
17. What is a vent hole in a thermit welding mold?
18. What mechanism is used to feed the metal to the metal spraying torch?
19. Must a gas mask be used when metal spraying?
20. Is the hydrogen furnace a form of welding or brazing?

CHAPTER XV

MANUFACTURE OF METALS

212. History

The first iron known to man came to the earth in form of meteors. This explains why the Egyptians called it the "metal of heaven." The first iron was used as far back as 3500 years B.C.

The forerunner of one modern blast furnace was the Catalan forge, developed in the 17th century. The Catalan forge was a shallow cavity made of brick and stone usually of an oval shape. A tube projected into the center of this cavity through which air entered. Air was supplied at first by a bellows and later water power was used to force the air through the mixture of iron ore, wood, and charcoal. A man by the name of Dudley, in 1620 substituted coal for the wood and charcoal and Abraham Darby introduced the use of coke as a fuel in 1618.

213. Methods of Manufacturing Steel

Steel is produced by several different methods, practically all of which originate with the blast furnace. The blast furnace is used to convert iron ore into pig iron or cast iron. This pig iron is then put into one of several types of furnaces which serve to remove the impurities and reduce the carbon content to form steel of various qualities. Some pig iron is remelted in cupolas and then made into castings (cast iron). Molten pig iron may be put into a Bessemer Furnace which burns out the impurities, and much of the carbon, producing good quality steel. The pigs may be put into an open hearth furnace with or without scrap steel and converted into steel.

Further, Bessemer Steel, open hearth steel and pig iron may be put into crucible furnaces or electric furnaces in which are made the fine steels and alloy steels.

214. Material Used by Modern Blast Furnace

Iron seldom exists free in nature, but is mined from the earth's surface in the form of iron ore or rust mixed with impurities in the form of clay, sand, and rocks. The most important types of iron ore are:

Hematite (red iron)	Fe_2O_3	70% iron
Magnetite (black)	Fe_3O_4	72.4% iron

Limonite (brown)	$Fe_2O_3H_2O$	60% iron
Siderite (iron carbonite)	$FeCO_3$	48.3% iron

Hematite is the most important ore in the United States and it comes from the Lake Superior and the Birmingham, Alabama district.

A good flux that will melt and combine with the impurities in the iron ore must be used. Limestone is used for this purpose as it carries the impurities off in the form of slag.

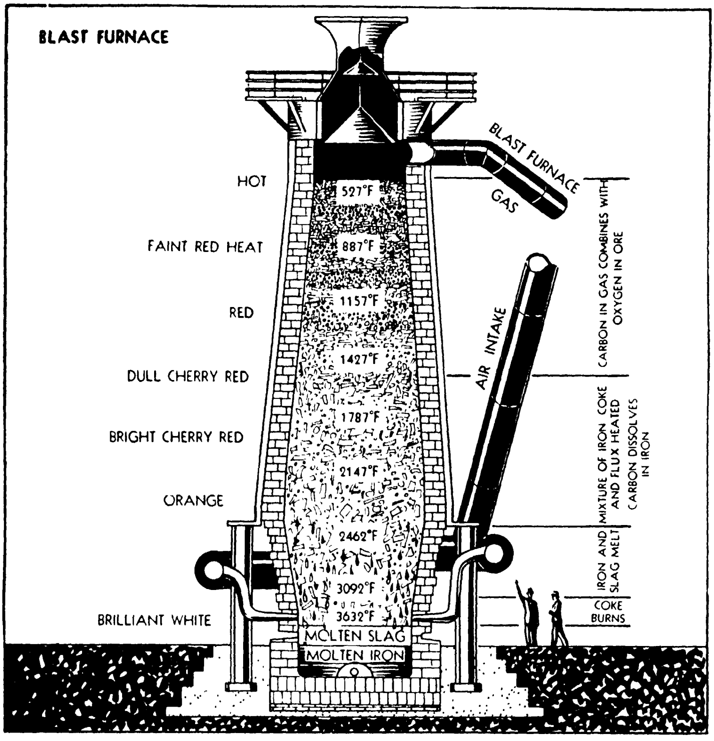


Figure 190. A cross section of a blast furnace
(Courtesy of: General Motors Corporation)

The best fuel for the blast furnace is coke as this furnishes enough heat for the reactions and is low in impurities in the form of sulphur and phosphorus.

Coke is manufactured by heating soft coal in a closed container until all the gases and impurities are driven off and only coke which is practically pure carbon remains. The gases driven off are condensed and furnish many by-products such as coal tar, gasolines. lubricating oil and fertilizers as well as coke over gas that can be burned to furnish heat and power.

215. The Blast Furnace

The blast furnace has five major operations to perform.

1. It must deoxidize the iron ore
2. It must melt the slag
3. It must melt the iron
4. It must carbonize the iron
5. It must separate the iron from the slag

The modern blast furnace is a huge tubular furnace made of steel and lined with fire brick. This furnace is approximately 100 ft. high and 25 ft. in diameter. See *Figure 190.* Around the bottom of the furnace are openings through which hot air may be forced and an opening near the top where the gases may escape. The ore, limestone and coke are carried up to the top of the furnace and dumped down into the furnace through a bell shaped opening.

The coke burns and causes enough heat to melt the iron. The excess carbon from the coke unites with the iron and lowers its melting temperature. The melted iron falls to the bottom of the furnace where it is drawn off when a sufficient quantity has collected. The flux melts and collects the impurities and this floats on top of the iron where it can be drawn off the furnace through an opening higher than the one through which the iron is taken out. The operation of the furnace is continuous and the right proportions of ore, limestone and coke are dumped in at the top of the furnace through charging bells. Every few hours a batch of the blast furnace iron (pig iron) is drawn off from the bottom of the furnace.

The iron coming out of the blast furnace is called pig iron as it was formerly cast into bars called pigs. In modern practice, some of this iron is not allowed to cool but is taken directly to the open hearth furnace where it is made into steel or to the Cupola furnace where it may be further refined and made into castings.

(For the chemistry of the blast furnace see Chapter 19.)

216. Cast Iron

Approximately ⅕ of all pig iron is used in the manufacture of Gray Cast Iron. Gray cast iron is a casting that has been cooled very slowly thus allowing some of the carbon to separate forming free graphite. This graphite causes the gray appearance. White cast iron (very hard and brittle) is made by cooling the casting quickly. Cast iron is usually melted in a cupola furnace where the pig iron is refined to eliminate some of the excess carbon and other impurities.

217. Malleable Iron

Cast iron is a desirable metal from which to make intricate machine parts as it is very fluid when molten and flows freely to all parts of a mold. It may be machined relatively easily. However it has several undesirable characteristics such as brittleness and lack of malleability. In parts demanding malleability or resistance to shock malleable iron must be used. Malleable iron is made by the prolonged heating or annealing of white cast iron at a temperature of approximately 1400° F. for many hours depending on the thickness of the casting. The casting is then allowed to cool very slowly.

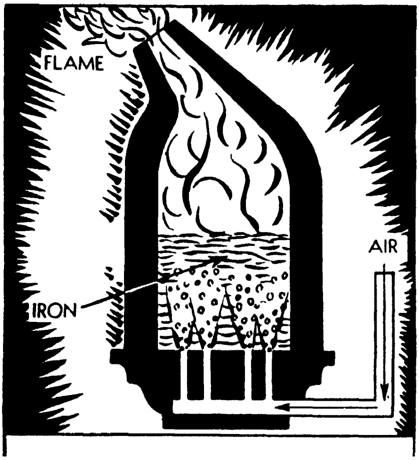


Figure 191. The Bessemer furnace
(Courtesy of: General Motors Corporation)

218. Wrought Iron

Wrought iron contains the least amount of carbon of any of the ferrous metals used commercially. Wrought iron is manufactured in the Puddling Furnace. To make wrought iron pig iron is melted on the hearth of the reverberatory or puddling furnace which is lined with iron oxide. This process brings about the almost complete removal of the carbon, silicon, and manganese. As the carbon is removed the fusion temperature of the iron raises and it becomes pasty and can be rolled up in balls and removed from the furnace. It is then squeezed through rollers to remove the excess slag, it is then rolled into muck bars and finally it is rolled into commercial forms.

Wrought iron is soft, tough and very malleable. It is very popular for ornamental work as it is rust resisting and may be easily welded.

219. Steel

Steel may be defined as iron combined with .003% to 1.7% carbon. See Chapter 16 for more technical specifications of steel.

220. Bessemer Furnace

One of the earliest methods of manufacturing steel was invented in 1856 by Henry Bessemer. The Bessemer Converter, see ***Figure 191,*** as the furnace is called, is a large pear shaped container lined with fire bricks and open at the top.

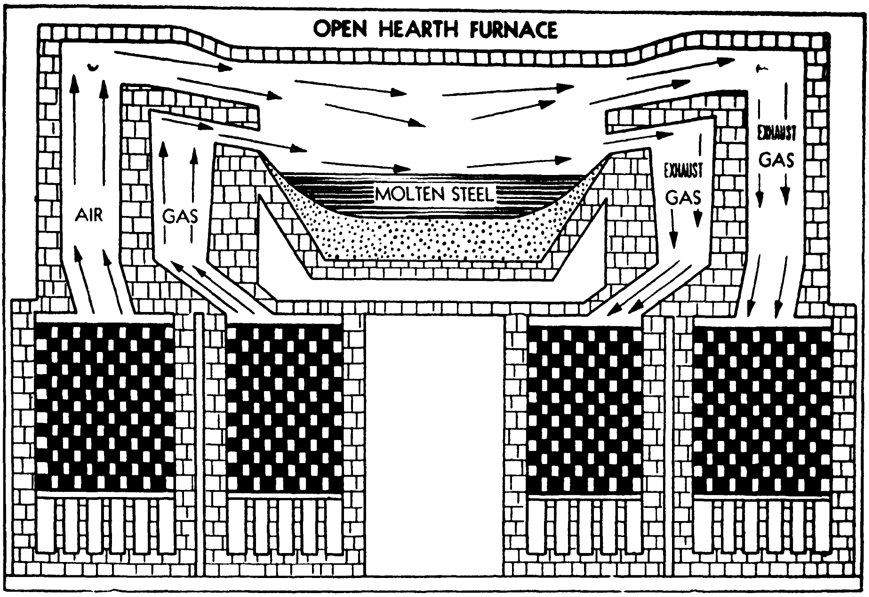


Figure 192. The open hearth furnace
(Courtesy of: General Motors Corporation)

Molten pig iron is poured into the furnace and a blast of air is turned on through holes in the motom. Each ton of pig iron contains about 75 lbs. of carbon, 25 lbs. of silicon, one lb. of sulphur, and 15 lbs. of manganese, most of which is burned out. These elements are the fuel. The temperature of the molten iron is about 2200 degrees F. when it is poured in the converter. In a few minutes after the blast of air is turned on, the burning of these elements in the iron raises the temperature to 3500 degrees F. The converter holds eight to ten tons of molten pig iron. A "blow" or charge treatment requires ten to fifeen minutes. Most of the carbon, silicon, sulphur, and manganese are burned out which causes

the mouth of the furnace to belch forth bright flames. No extra fuel is necessary.

When the impurities are burned out the color of the flame changes and the air is turned off. The correct amount of carbon and manganese are now added to the molten steel to give the desired composition. The steel is then poured into ingots to be rolled to the shapes desired.

221. Open Hearth Furnace

This is by far the most popular method of manufacturing steel today and was invented in 1861 by Siemens. This method is sometimes called the Siemens-Martin Open Hearth Process, being named after the men who developed this method of manufacturing steel.

In this furnace, see *Figure 192*, the metal is contained in a large shallow vat, holding from 150 to 300 tons of metal. At each end of the furnace are two openings to admit the fuel and air. As the gas and air burn over the top of the metal they pass out over the other end through bricks arranged in a checker board pattern. The heat of the escaping gases is used to heat the bricks and then the directions of gas and air are reversed and the heat stored in the bricks is used to heat the gas and air before it is burned. This preheating makes it possible to obtain much higher temperatures in the furnace than if cold air and gas were burned. The directions of flow is reversed every 15 to 20 minutes. This is called the regenerative process of heating. The total time for processing each charge is 20 to 30 hours.

The high temperatures obtained by this process aids in burning out the carbon and impurities in the iron to make steel. The advantages of this process are:

A. Less steel is lost in the process.

B. A better control over the alloying elements is obtained.

C. Steel is cleaner because it contains fewer oxides.

D. Larger batches of steel may be made at once.

E. Pig iron unsuitable for the Bessemer process may be made into steel by the open hearth method.

F. Steel manufactured by the Bessemer process may be further refined in the open hearth furnace.

Some open hearth furnaces are made so the entire furnace may be tilted to facilitate tapping and pouring.

222. Electric Furnace

A popular method used to manufacture the better steels is the electric furnace. In this process chemical constituents of the metal may be closely controlled and various alloys may be also added if desired. All of the elements required are put into the furnace at each charge and the furnace is then sealed. The heat is usually furnished by putting the two large electrodes made of carbon through the top of the furnace. The furnace is usually built so that it may be tilted. The capacity of these furnaces varies from 5 tons to 50 tons. *Figure 192A.*

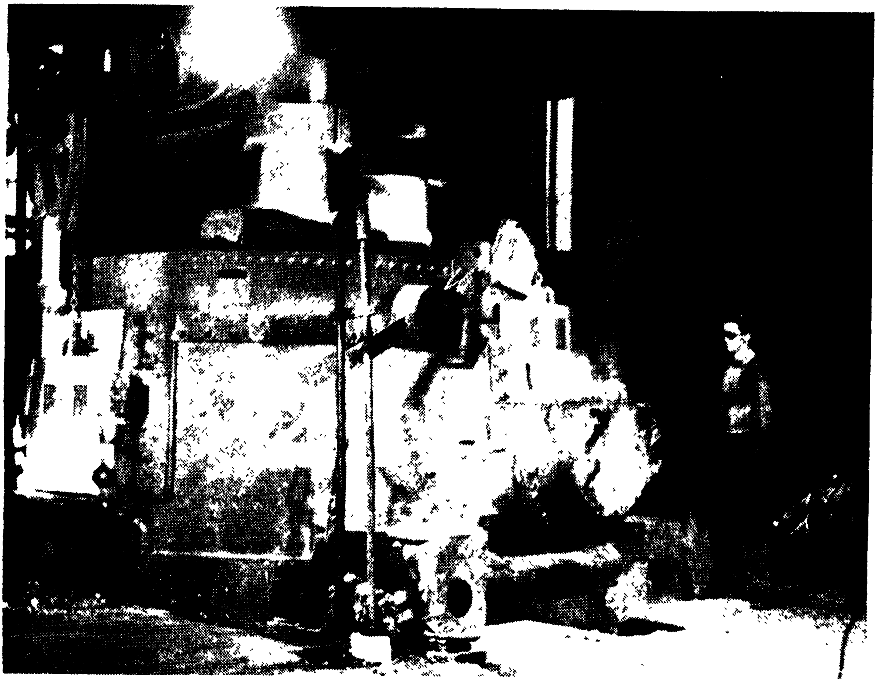


Figure 192A. An electric furnace. Note the carbon electrodes at the top
(Courtesy of: American Iron and Steel Institute)

223. Crucible Furnace

One of the oldest forms of refining steel is the crucible furnace. The heating is usually done by gas and the various charges are put into clay or carbon crucibles and then sealed. The heating is external and extremely high quality steel of practically any type may be made this way. The quality of the steel from crucible furnaces usually is considered better than that obtained from electric furnaces but the process is slower and more expensive. The charge in a crucible varies from 100 pounds to 5 tons.

224. Manufacturing Stainless Steels

Stainless steel, the most common of the alloy steel, is made in open hearth furnaces exactly similar to straight carbon steels with the alloy metals added during the time the metal is in the furnace. Alleghany metal, Enduro, 18-8 Steel are examples of this steel.

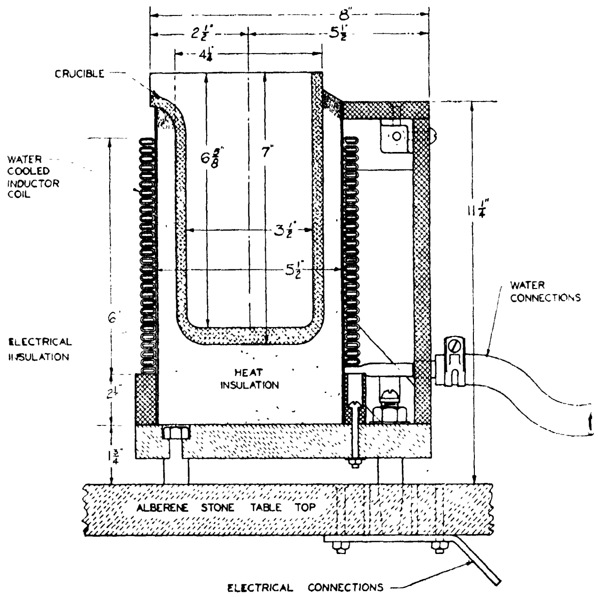


Figure 193. A cross section of a 12 pound induction furnace
(Courtesy of: Ajax Electrothermic Corporation)

225. Manufacturing Copper

Much copper is found in a pure raw state and the pure metal is removed by crushing and washing away the impurities (stone, earth, etc.). Considerable copper is secured by using the electrolytic process to remove it from its ore. The ore is first smelted in a blast furnace and the sulphur and the impurities burned away. The cast slabs are then further reduced by the electrolytic method.

226. Manufacturing Brass and Bronze

Brass and Bronze are alloys of high copper content with various other matter added in a gas heated crucible or an electric cupola. There are a considerable number of these alloys each having its special application, i.e.

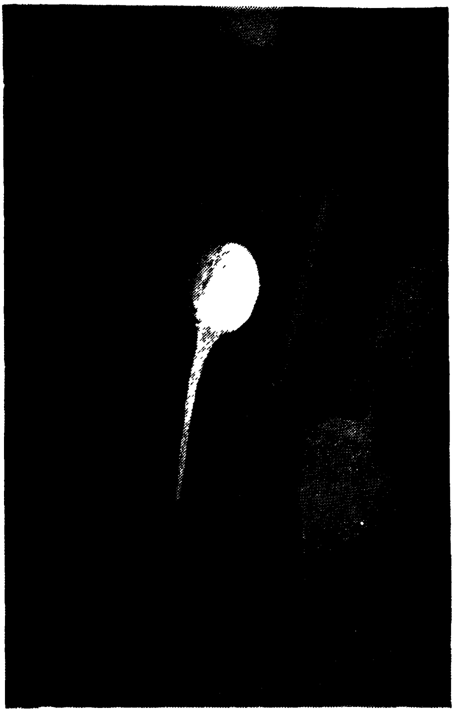


Figure 193A. Pouring metal from an induction furnace
(Courtesy of: Ajax Electrothermic Corporation)

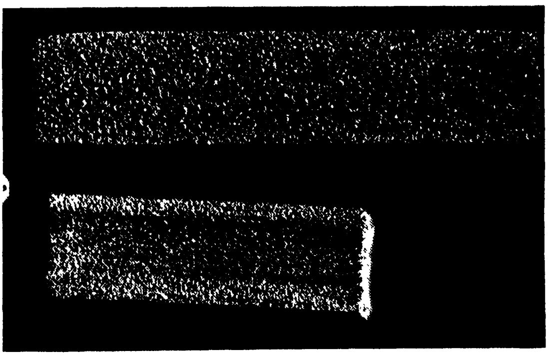


Figure 194. A macrograph (4X) of etched steel; the upper figure is across the grain of rolling and the lower figure is along the grain of rolling

A. Brasses (Copper and Zinc)
   1. **Best Yellow Brass** (30% zinc)
   2. **Muntz Metal** (40% zinc)
   3. **Nickel Silver** (24% zinc, 15% nickel)

B. Bronze (Copper and Zinc)
   1. **Bell Bronze** (25% tin)
   2. Art bronze (7% tin)
   3. Aluminum bronze (11% aluminum)

The remainder of each of the above alloy is copper.

227. Manufacturing Aluminum

Aluminum is obtained by separating it from its oxide (bauxite) although it is found in many other forms. After dissolving it in a molten bath of sodium-aluminum fluoride the aluminum is obtained by use of electricity. (Hall Process)

228. Manufacturing Zinc

Zinc is principally produced by a distilling process. The zinc ore is heated with coke in a clay crucible and the zinc vapor is then condensed in a clay condenser. It may also be refined by an electrolytic process. It is used mainly as an alloying metal and for galvanizing.

229. Shaping Metals

All of these metals are originally cast. These castings are sometimes trimmed to remove impurities, remelted and cast again. *Figure 193.* The castings are then heated to a definite temperature depending on the metal and shaped by one or more of several methods. *Figure 193A.* Some of the most common shaping methods are:

A. Casting
B. Rolling (hot or cold)
C. Forging
D. Extruding
E. Drawing

Casting a metal in either sand or metal forms using the stationary mold or the centrifugal mold is a very popular method of obtaining the desired part. To improve the physical properties of the metal or to obtain a shape not natural by casting, metals are rolled, either hot or cold. *Figure 194.* This process may involve many operations. Forging, either drop or press, is used to obtain shapes stronger than castings and not easily rolled. Extruding metal through a die when the metal is either hot or cold enables lengthy pieces of cross-sections not easily rolled. Drawing metal through

dies (wire, tubes, etc.) is also a popular method of finally shaping metal to meet certain requirements.

230. Review Questions

1. What materials are put into a blast furnace for producing pig iron?
2. How long does a charge remain on "blow" in a Bessemer furnace?
3. What fuel is used in a Bessemer furnace?
4. In what furnace is stainless steel most commonly made?
5. What types of steel does the crucible furnace produce?
6. What is the name of the most common aluminum ore?
7. Is molten pig iron part of the open hearth change?
8. What is a tuyere?
9. What fuel is used for the open hearth furnace?
10. What is the most popular steel producing furnace?

CHAPTER XVI

PROPERTIES AND IDENTIFICATION OF METALS

It is necessary for a good welder to have some accurate means of identifying metals and he must also have a good understanding of the constituents of metals in order that he may intelligently proceed with any welding problem. Metals are divided into two major fields. (1) The Non-Ferrous Metals. (2) The Ferrous Metals. The non-ferrous metals consist of those metals and alloys not having iron. They include any combinations of carbon and other metals with iron. Naturally the welder devotes most of his time to welding iron and carbon metals which range from wrought iron up through mild steel, tool steel, and cast iron. Some of the more popular non-ferrous metals a welder encounters are copper, brass, zinc, bronze, lead, aluminum, and die castings.

231. Iron and Steel

Iron is a chemical element belonging to the metal family; and it is produced by reducing iron oxide, commonly called iron-ore, to pig iron by means of the blast furnace.

Many types of furnaces, are then used to change the pig iron into the various steels. Some of these furnaces are: the open hearth furnace, the Bessemer furnace, the electric furnace, and the cupola furnace. See Chapter 15.

Usually the carbon content in the iron determines the quality of the steel. For example, wrought iron has .003 per cent carbon, meaning three thousandths of one per cent. Mild steel contains, on the average, .15 per cent carbon. High carbon steel contains approximately .75 per cent carbon. Tool steel contains approximately 1.25 per cent and cast iron contains 2¼ to 4 per cent carbon. The carbon generally combines with the iron to form iron carbide, a very hard, brittle substance. This action means that as the carbon content of the steel increases, the hardness of the steel also tends to increase. In addition, the metal becomes stronger and usually more brittle. Various heat treatments are used to enable steel to retain the strength of its higher carbon content, and yet not have the extreme brittleness usually associated with high carbon steels. Also, certain other substances such as silicon and other alloying metals

are added to the metal to enhance or heighten certain qualities of the steel.

A welder must also have an understanding of the impurities occasionally found in metals and their effect upon the weldability of the metal.

The two most common impurities found in steels are phosphorus and sulphur. Their presence in the steel is due to their presence in the ore, or to their method of manufacture. Both of these impurities are detrimental to the quality of the steel; therefore during the manufacturing process, extreme care is always taken to keep these impurities at a minimum (.05% or less).

During a welding operation, any amount of sulphur or phosphorus tends to form gas in the molten metal, resulting in holes in the welds, and in an increasing brittleness because of the sulphites and phosphates formed. Another impurity, usually resulting from the mechanical shaping of the metal to its final form, is dirt (or slag) imbedded in the metal by the rollers. This consists principally of iron oxide, although some of the dirt may come from the by-products of the process of refining the metal. These impurities may also produce blow holes in the weld and destroy the properties of the metal in general.

232. Physical Properties of Iron and Steel

As mentioned previously, the physical properties of steel are affected by the following: (1) the change in carbon content (2) the addition of various alloy metals, and (3) the heat treatment. What is usually meant by the physical properties of the metal are its strength in tension, compression, shear, and impact. Chapter 7 describes various machines for determining these physical properties. As mentioned above modifications of these testing machines are being introduced to the welding shop to enable one to identify these metals.

Some of the more important physical properties of steels are:

1. Tensile strength
2. Ductility
3. Hardness
4. Brittleness
5. Compressibility
6. Elongation
7. Malleability
8. Grain size

Before these properties may be studied in detail, one must have an understanding of the effect of carbon on the properties of steel, and a thorough knowledge of alloys in general.

233. Alloy Metals

Any two or more metals in intimate mixture form an alloy. A simple alloy consists of two metals in any proportion. A sample of this alloy is the combination of lead and tin. The melting temperature of the lead is 635° F., while tin has a melting temperature of 432° F. However, as the two welds are mixed, any combination of the two results in a lower melting temperature. At a certain proportion of the metals, the lowest melting temperature is reached, which is lower than the melting temperature of either of the two pure metals separately. This point is called the eutectic point.

234. Cooling Curves

Although a metal melts under a certain pressure (atmospheric), the temperature of the metal remains constant during this change unless there is an absorption, or release, of energy within the molecular structure itself. For example, if a metal is heated to its melting temperature, a thermometer will show a steady rise in temperature per unit of time until the metal melts. As it melts, however, the temperature will remain constant. On some alloys internal changes take place below the melting temperature as the metals are being heated or cooled. With these metals the cooling or heating, or energy release on cooling.

This pause, or absorption of energy on heating, is due to atomic changes and is called accalescence, while the energy release on cooling is called decalescence. This point signifies a crystalline structure change in the metal, and causes the metal to expand (heat), or contract (cool) suddenly. The heat treatment of a metal through this crystalline structure change is of tremendous importance. These critical points, as they are sometimes called, are the important points observed in all heat treating methods. The cooling curves for steels illustrate decalescence and accalescence very well. Some samples of steels show two of these points on cooling and heating while some show only one. If for every carbon content, i.e., 5 point, 10 point, 15 point, etc., a cooling curve and heating curve were plotted, one would soon perceive that the points of accalescence and decalescence change with the carbon content. If a graph is made plotting the accalescence and decalescence points for the various carbon contents against temperature, the result is the iron-carbon diagram.

235. Iron-Carbon Diagram

The diagram, *Figure 195* shows the melting temperatures for each carbon content and, more important, it shows the critical points. Note that some of the areas are labeled cold working, hot working, forging, welding, etc. Note that the amount of carbon is very small. In most steels it is less than 1% which causes most steel men to call each 1/100 of one per cent one point. One carbon steel (a high carbon is called 100 point steel while $\frac{1}{10}$ of one per cent carbon steel is called 10 point carbon steel.

Referring to *Figure 195* some of the outstanding features of iron-carbon combinations are immediately understood. First, it is quite clear that up to a percentage of 40 point carbon there are three critical points occurring within the steel as the temperature carbon combinations are immediately understood. First, it is quite clear that up to a percentage of 40 point carbon there are three changes. As the temperature changes from 40 point carbon to 85 point carbon, the critical temperatures occur twice. At 85 point carbon content there is only one critical point. Finally, from 85 point to 170 point carbon there are only two critical points. Above 170 point carbon are included gray cast iron, white cast iron, and malleable iron. Not all the critical points are of especial importance to the welder; but the lowest temperature point is of great importance, occurring at approximately 1350° F. This is the temperature to which one must heat for hardening, annealing, tempering, etc.

As a specific example, follow the changes when 20 point carbon steel or .2 per cent carbon steel, which is known as mild steel, or technically speaking as hypoeutectoid steel, is taken through the complete temperature range. As the temperature rises, first the combination is ferrite metal with very little cementite (iron carbide) up to 1350° F.; second, if 20 point carbon steel is heated up to the temperature of 1350° F. and then allowed to cool slowly, the steel will be annealed. The temperature of 1350° F. is the temperature wheer the crystalline structure changes. At this temperature the crystals are the smallest (finest). Some of the grains consist of pure iron which are called ferrite, while other grains consist of iron-carbide, called cementite. When the grains appear in alternate layers or rows of ferrite and iron-carbide, the metal has a pearly appearance under a microscope. This condition is called pearlite, a name developed from this appearance.

Upon increasing the temperature above 1350° F. a point is reached labeled the best heat for mechanical working, meaning that

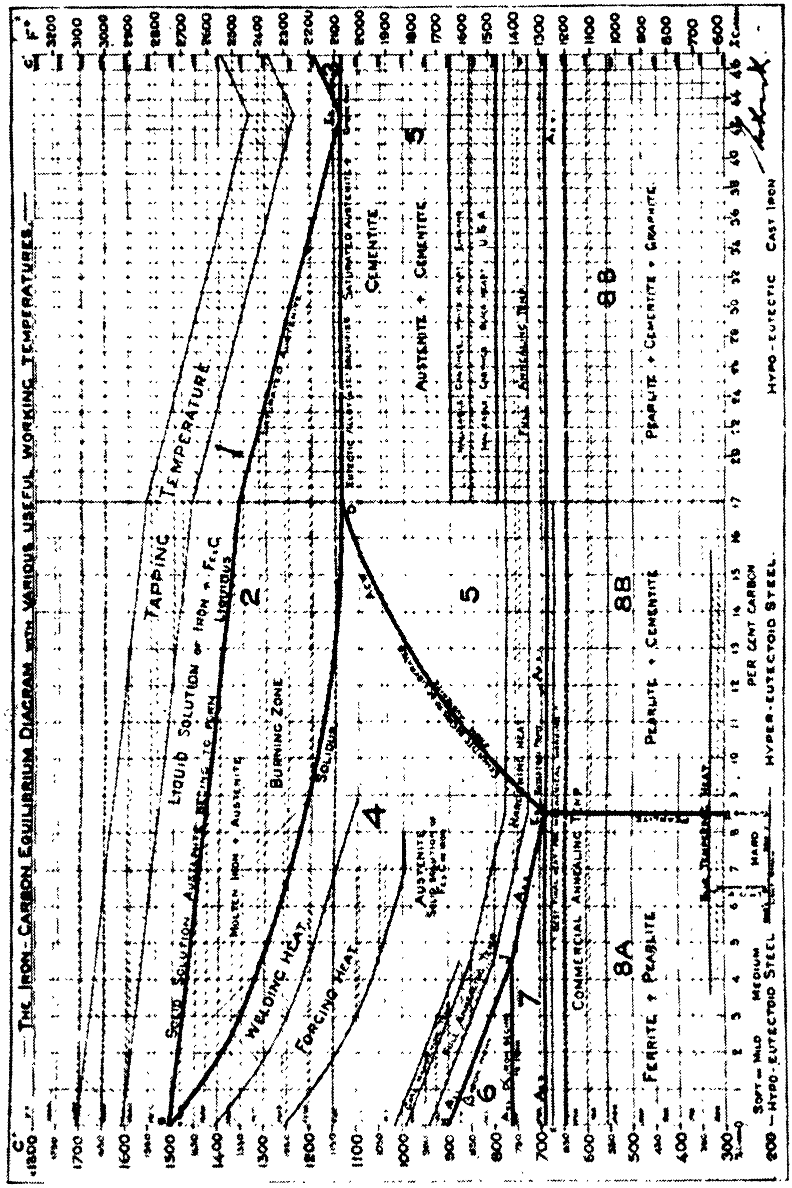


Figure 195. Iron-carbon diagram
Courtesy of: Champion Rivet Co.

when the steel is heated to this temperature, it may be worked by means of rollers and pounding, without fracture occurring.

When a temperature slightly over 1600 degrees is reached, a new change occurs and the steel is labeled iron alpha. The steel, while at 1500° F., is changed to the beta form. These terms (alpha and beta) are technical divisions, or iron-carbon combinations, and have no direct bearing upon the practical treatment of steel.

Slightly above this temperature, however, at approximately 1600° F. to 1700° F. the iron turns into gamma iron. If the steel is heated to this temperature and then allowed to cool slowly, the steel will be in its softest possible condition. However, the crystal size will be much larger than if the steel were heated only to 1200° F.

When it is desired to increase the carbon content of mild steel, a temperature slightly above its annealing temperature is used. If the steel is exposed to carbon at this temperature, the steel will gradually increase in carbon content (case hardening process). The outer surface of the metal at this temperature will take some of the carbon, thus producing an increased carbon content in the skin of the metal. This process is used when a hard surface is desired along with a strong tough interior.

If the metal is heated to a higher temperature, it reaches the range in which the metal can best be forged (plastic range), while just above this temperature (from 2350° F. to 2550° F.) is the welding temperature of the metal. Here the metal is molten, but at this temperature it will not burn. From 2650° F. and up, the 20 point carbon steel is in the burning zone, meaning the spontaneous oxidizing zones. This temperature is labeled the burning zone in *Figure 195*.

From this description one may readily see that the temperature under which metal is worked, or to which the metal is heated, has a decided bearing upon its properties. Twenty point carbon steel is a very common steel, and one should try to remember the approximate conditions listed above.

It is interesting to note that as the carbon content is increased, the commercial annealing temperature and the mechanical working temperature remain approximately the same. However, the full annealing temperature decreases as the carbon content increases up to 85 point carbon, as does the forging temperature and the welding temperature.

Beyond the 45 point carbon steel point, the case-hardening temperature is of no special significance as the metal may now be hardened without having any carbon added.

Welding steel will always ruin any heat treatment, or any properties of the metal that are the result of mechanical working. To

renew these properties, the metal must again be heat-treated and mechanically worked.

One may also notice that the forging temperatures and welding temperatures are not listed above 70 to 75 point carbon, because forging metal that has more than 70 point carbon is not practical. Bronze welding, rather than fusion welding, is recommended for steels above 70 point carbon until the cast iron range is reached.

Above 170 point carbon, welding may be used again. To attempt to weld steel between 85 and 170 point carbon usually subjects the steel to the burning point temperature which will always affect the carbon content. High carbon steel, during welding, boils vigorously and becomes brittle and porous. Above the line BDE_c the steel is nearly all molten, while below this line the metal is in a solid state; but the crystal size and the proportions of the compounds in the metal change.

Above the horizontal line passing through eutectic point labeled E_d at 85 point carbon steel, the temperature between 1350° F. and 1450° F. is labeled the hardening temperature. If steel of 85 point carbon to 170 point carbon is heated to this temperature and then cooled very rapidly, the metal will be very hard. Annealing this metal requires that it be cooled as slowly as possible from the above temperature.

The size of the crystals in a metal determine to a great extent its strength and ductility. If 15 point carbon steel is heated, the crystal size will not change until a temperature of approximately 1350° F. is reached. At this point the crystals change to their smallest and most refined state. If the metal is cooled rapidly from this temperature, the crystals will be very small. The metal is now at its maximum strength, but will not be extremely ductile. If the metal is heated to a temperature higher than the 1350° F. point, the crystals gradually increase in size; if the metal is cooled slowly from any temperature higher than the 1350° F., the crystal will become steadily larger until 1350° F. is reached. But from 1350° F. down, the crystal remains the same size. Time is an important element in heat treating because if the metal is kept above the critical temperature for any period of time, the crystal size will increase steadily to a maximum size. See Chapter 17 for more details on heat treating.

236. Identification of Iron and Steel

Because of the effect on the properties of steel caused by the above three variables, carbon content, temperature, and time, a welder

must determine quite accurately the nature of the steel being handled. The manufacturers' specifications for the particular steel are the most desirable. Whenever possible the welder should obtain these and keep them on file; while at the same time he should mark the metal to correspond with filed information. However, in many cases, this knowledge is not readily available, and the welder must use other methods to discover the nature of the metal.

Many tests have been developed to do this, and of these, the following are the most common:

1. The spark test (with the power grinder)
2. The oxy-acetylene torch test
3. The fracture test
4. The color test
5. The density or specific gravity test
6. The ring or sound of the metal upon impacting with some other metal
7. The magnetic test
8. The chip test

Of the above tests, the last six should take place almost subconsciously in the welder's mind, as he works on the metal. The spark test and the gas torch test must be done under carefully prepared conditions. These tests indicate to a remarkably accurate degree the properties and constituents of the metal.

237. The Spark Test

A method of identifying metals, which was developed and carefully analyzed by Mr. John F. Keller, of Purdue University, is extensively used by welders to identify irons and steels. A power grinder is used as the test equipment. When testing a sample, if one touches the rim of the revolving wheel *lightly* with the metal, the sparks resulting from the contact are found to differ in character for different steels. Heat treatments have some effect on the nature of the spark. The lighter the contact, the better; and one should use a black background to better identify the spark. One must always wear goggles when grinding; the grinder must be inspected to see that it is in good condition before one proceeds with this test. Four outstanding features of the spark generally denote the nature, and condition of the steel; they are:

1. The color of a spark
2. The length of the spark

3. The explosions (sparking or forking) of the individual sparks.

4. The shape of the spark.

For example, a mild steel containing 20 point carbon (.20%) will show a long white spark streamlined in shape, which will jump approximately 40 to 50 inches from the power grinders. Some of these sparks will suddenly explode, shooting off smaller sparks

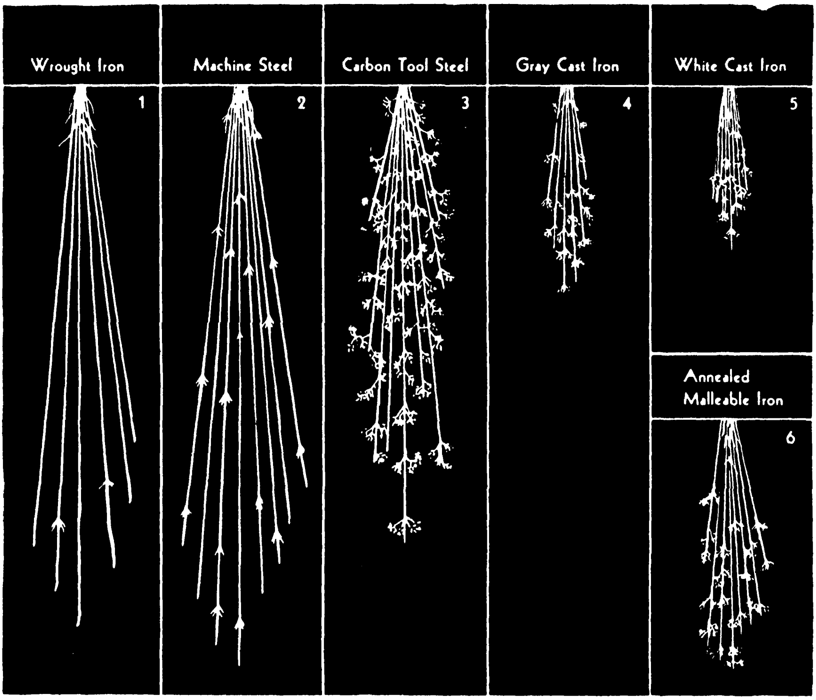


Figure 196. Spark test for common steels
(Courtesy of: Norton Company)

at approximately 45° angles to the direction of travel of the original spark. A 30 point carbon steel will have sparks almost identical to the .20 point carbon steel with the exception that more of the streamlined sparks will explode while the total length of the sparks will decrease slightly. This serves to show that as the carbon content of steel increases, the explosions of the sparks become more frequent. Also, as the carbon content increases, the length of the spark is decreased because of the interruption during their flight of the individual explosions. *Figure 196.* For example, a high carbon steel, containing 80 point carbon, has a very short spark with explosions occurring so rapidly that it is hard to identify the

Metal	Volume of Stream	Relative Length of Stream, Inches †	Color of Stream Close to Wheel	Color of Streaks Near End of Stream	Quantity of Spurts	Nature of Spurts
1. Wrought iron	Large	65	Straw	White	Very few	Forked
2. Machine steel	Large	70	White	White	Few	Forked
3. Carbon tool steel	Moderately large	55	White	White	Very many	Fine, repeating
4. Gray cast iron	Small	25	Red	Straw	Many	Fine, repeating
5. White cast iron	Very small	20	Red	Straw	Few	Fine, repeating
6. Annealed mall. iron	Moderate	30	Red	Straw	Many	Fine, repeating

† Figures obtained with 12" wheel on bench stand and are relative only. Actual length in each instance will vary with grinding wheel, pressure, etc.

Figure 197. Table of spark test characteristics of common iron and steel
(Courtesy of: Norton Company)

streamlined iron dashes. The sparks dissipate themselves very rapidly.

When higher carbon content metals are tested, one may become confused between extremely high carbon steel and cast iron. The characteristics of the two on the basis of the spark are almost identical. *Figure 197.* However, the cast iron spark, when leaving the point of contact, is a very dull red and the spark jumps only 10 to 12 inches from the wheel; while a high carbon steel of approximately 130 point carbon has a faster disappearing spark and the length of the spark is usually somewhat longer. Both of these metals show a small spark expiosion at the extremity of the spark flight; the amount of the spark in these two cases is considerably less than one would expect from such a high carbon content.

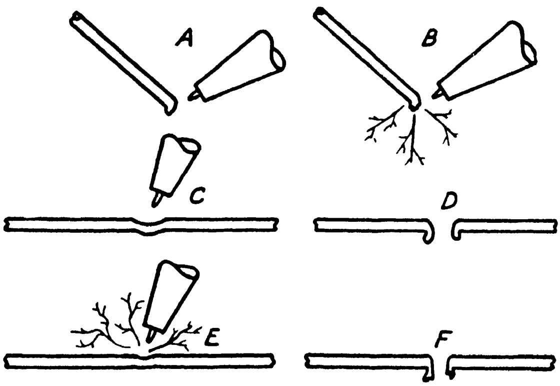


Figure 198. The blow-pipe (torch) test: A. Good quality filler rod, B. Poor quality filler rod, C. & D. Good quality base metal, E. & F. Poor quality base metal

238. The Oxy-Acetylene Torch Test

Even if one knows the physical composition and the chemical composition of a metal, the welder must know also whether the metal has good welding properties. For example, some cold rolled sheet steels may show very good physical and chemical properties, but during some part of the manufacturing process, impurities have been added to it or certain work was done on the metal affecting its properties to the extent that during welding the metal will not melt readily, will not fuse readily, and the final weld may be burned and porous. The usual cause of this condition is that there are impurities imbedded in the metal in the form of slag and roller dirt. For these reasons a welder should subject steel to the torch test.

The actual test consists of melting a puddle in the steel. If the metal is thin, the puddle penetrates through the thickness of the

steel until a hole is formed. This puddling should be done with a neutral flame, held at the proper distance from the metal. The puddle should not spark excessively; and it should be fluid; the puddle should not boil, and it should possess good surface tension. The appearance on the edge of this aperture is very indicative of the weldability of the steel. If the metal that was melted has an even, shiny appearance upon solidification, the metal is generally considered as having good welding properties. However, if the molten-metal surface is dull or has a colored surface, and if this surface is rough, perhaps even broken up into small pits or porous spots, the metal is generally unsatisfactory for welding.

This test is accurate enough for most welding. The test is very easily applied with the equipment on the premises and determines the one thing that is fundamentally necessary in any welding job, that is, the weldability of the metal. *Figure 198.* While performing the weldability test of the metal, it is important to note the amount of sparking emitted from the molten metal.

239. Miscellaneous Identification Tests

As an added precaution to the above tests, six other tests are occasionally used by the welding jobber. The fracture test is used extensively and consists of breaking a portion of the metal in two. If it is a repair job, the fractured surface is ready for inspection. The appearance of the surface where the metal is cracked shows the grain structure of the steel. If the grains are large, the metal is brittle and weak; if the grains are small, the metal is usually hard and brittle, or soft and ductile. The fracture shows the color of the metal which is a very good means of identifying one metal from another, and the test also indicates the type of metal by the ease with which it may be fractured. *Figure 199.* As mentioned above, the fracture gives a very good indication of the color of the metal. The two main divisions of metals include the irons and steels which are indicated by their typical gray white color, and the non-ferrous metals which come in two general color classifications of yellow and white. Copper may be rather easily identified by a welder and the same applies to brass and bronze. Aluminum, white metal, die-casting metal, aluminum alloys, zinc, and the like, are all of somewhat the same color although they may vary in shade.

The metals may also be differentiated by means of the weight or density test of the specimen. A perfect example of identification by density or specific gravity is identifying aluminum and lead. Roughly speaking, their colors are somewhat similar, but anyone may

readily distinguish between the two metals because of their respective weights.

The ring test, or the sound of the metal test, is an easy means of

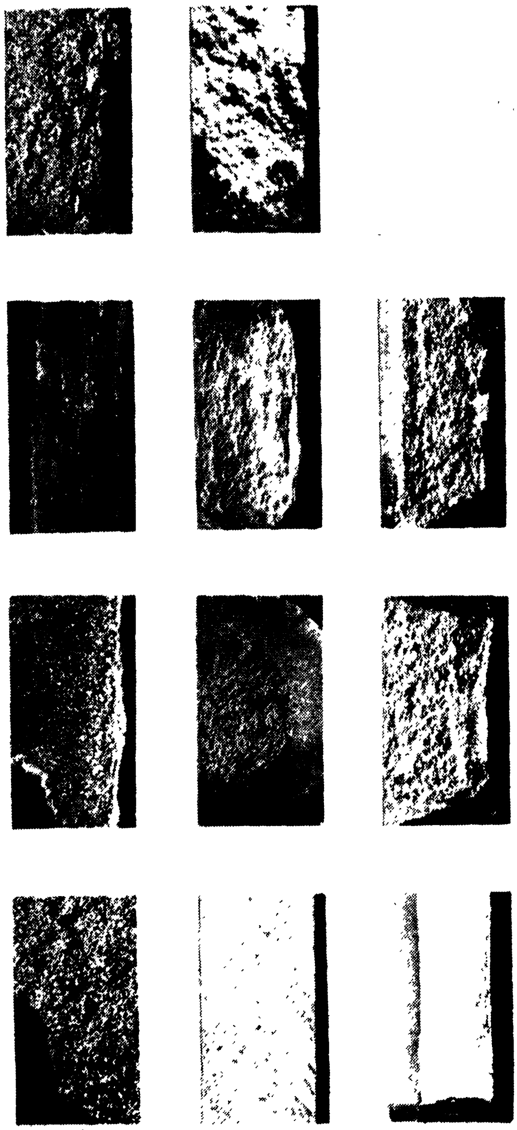


Figure 199. The fracture test
(Courtesy of Linde Air Products Company)

identifying certain metals, one from the other, after one has had some experience with this method. It is used extensively for identifying heat-treated steels from annealing steels, and is also used to

detect alloys from the base metal. An example of the latter is aluminum and duralumin. The pure aluminum sheet has a duller sound, or ring, than the duralumin which is somewhat harder and has a more distinct ringing sound.

The magnetic test is an elementary test used to identify iron and steel metals from the non-ferrous metals. Generally speaking, all steels are affected by magnetism while the non-ferrous metals are not. Everyone has seen the commonly applied salvage use of this test; the same test may be used commercially to separate steels from non-ferrous metals in salvage operations.

Another test which must be accompanied by a considerable experience is the chipping test of a metal in which the cutting action of the chisel indicates its structure and heat treatment. Cast iron, for example, when being chip-tested, breaks off in small particles; but with mild steel the chip tends to curl and cling to the original piece. The higher-carbon, heat-treated steels cannot be tested this way because of their hardness.

240. Chemical Tests to Identify Metals

At the present time chemicals are not used extensively for identifying metals in the welding shop. However, as different chemicals are developed this usage will grow. The tests in themselves are rather simple; the chemical is applied to the metal surface of a sample, or the metal is immersed in some chemical solution and the resulting reaction noted. This test is especially useful for alloy metals.

To identify aluminum from its alloys use a caustic soda solution. Expose the metal to a solution of 25% sodium hydroxide and 75% water by weight for 2 or 3 minutes. The pure aluminum will stay bright while the dural or any copper bearing aluminum will turn dark.

Nickel steel may be identified by dropping some 50% water acid solution on the cleaned metal for ½ minute. Blot the drop and then add some dimethylglyoxime solution is made by mixing 1 gram ammonium acetate, 1 gram dimethylglyoxime, 75 cubic centimeters of acetic acid and 30 cubic centimeters of concentrated ammonia (28½).

A popular aircraft steel, chrome-molybdenum steel, is identified by immersing some filings or drillings in dilute sulphuric acid. As the steel finishes dissolving, the solution will turn a deep green. A rough test between mild carbon steel and chrome-moly steel is in the relative hardness of the metals while being hacksawed.

241. Identification of Iron and Steel Alloys

The alloys used in iron-carbon metals are provided to develop or improve the various physical properties of the metal. A common illustration includes the stainless steels in which alloy metals are used in the steel to make the steel corrosion-proof. These metals consist of various combinations of chromium, nickel, and copper. Other alloys may be used in steel to increase its strength, hardness, and toughness. A good example of this type of alloy is the use of tungsten. The addition of a small amount of tungsten metal to steel produces an extremely hard metal without sacrificing its other properties to any appreciable extent. Low-carbon alloy steels are sometimes improved by the alloying with various amounts of nickel or copper. These alloys serve the purpose of producing stronger steels at a minimum cost. See Chapter 12. Heat treatment is most important in determining the physical properties of alloy steels.

During the last decade, extensive research has been carried on with iron and carbon steels in which other metals have been added to improve or bring out certain properties. The two main fields in which this development has taken place are in the stainless steels and in the low-carbon-alloy steels. There are also many other combinations which are being tried. These metals are difficult to identify from ordinary steels, and their composition greatly affects their welding properties. The development of these new metals may result in the development of more accurate identifying equipment for the welding shop.

It would assist the welder greatly if all metals could be stamped or labeled in some permanent manner to enable the person working with them to determine the type of metal being used.

The most common metals alloyed with iron and steel to bring out properties are as follows:

a. Stainless steels
   (1) Chromium
   (2) Nickel
   (3) Copper

b. Low-carbon-alloy steels
   (1) Copper
   (2) Nickel
   (3) Silicon

There are several well known standard stainless alloys, the most common of which is the 18-8 combination, which means 18% chro-

mium and 8% nickel. The application of stainless steels is well understood. Their corrosive resistance properties, and their ability to produce and retain a high lustrous finish, make them usable for vessels of all kinds, decorative purposes, and for kitchen and table ware.

One example of a low-carbon-alloy steel is one containing 25 point carbon, 6% copper, 3% nickel and 2% silicon. These low-carbon-alloy metals have recently come into the picture, and are extensively used for fabricating work and for structural work of all kinds,

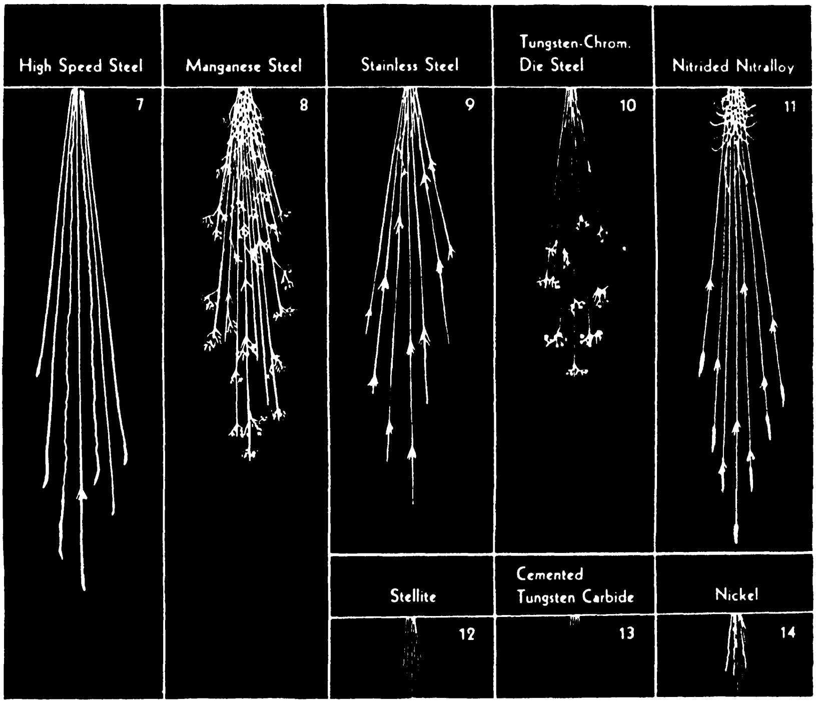


Figure 200. Spark test for alloy steels
(Courtesy of: Norton Company)

where the high strength of these alloys enables a reduction of weight without sacrificing strength. They are also used extensively in fabrication involving arc-welding, often replacing large, cumbersome, and expensive castings.

242. Spark Test for Alloy Steels.

The appearance of the power grinder spark for alloy steels varies considerably, depending upon the alloys included in the metal. The basic spark, that is the carbon spark, is identical with the straight,

iron-carbon steels in the number of the spark explosions increasing, the length of the spark flight decreasing, and the color of the spark becoming brighter and brighter as the carbon content increases. The principal variations the alloy elements give to a steel are the multitude of right-angle, branch-off sparks which result from the alloys in the metal and the change of color of the spark.

As an example, a manganese steel has only a slight indication of the spark explosion, but the manganese causes the sparks to shoot out at right angles to the flight of the original spark, and these sparks tend further to explode, producing the effect of the leafless branched tree, or lightning. *Figure 200.*

Chromium and tungsten steels, which are used for high speed work, show the typical, high-speed spark with the exception that the color of the spark turns to a chromium yellow at the end of its flight; the chromium and the tungsten have a deteriorating effect on the carbon spark, causing it almost to disappear. *Figure 201.* The spark is also an interrupted one, that is, it disappears for a portion of its flight and then appears again.

243. Torch Test for Alloy Steels

It is impossible to give rigid specifications of the torch-melting test for all alloy steels. However, it is generally known that the higher the alloy constituents, the more difficult it is to weld the metal. Under the influence of the torch flame, the metals have a tendency to boil, because of the action of the alloys in them, and special fluxes may be of considerable help in welding them.

Stainless steels are available in many varieties. The most common are not difficult to weld, and they show no outstanding characteristics under the torch flame. Manganese steel is steel used for special abrasive work, and the only application of welding in this case is to build up the worn surfaces. The steel melts readily under the torch flame and presents no difficulties.

Nickel steels can be identified under the torch flame by the excessive boiling of the metal. Results tend to be unsatisfactory, although it can be done with some success by using fluxes. Nickel-chrome steels present the same difficulties. Chrome steel is easily welded under the oxy-acetylene flame, but the method is not recommended because of the destruction of the corrosion-resisting properties of the metal and the increase in brittleness.

Metal	Volume of Stream	Relative Length of Stream Inches†	Color of Stream Close to Wheel	Color of Streaks Near End of Stream	Quantity of Spurts	Nature of Spurts
7. High speed steel	Small	60	Red	Straw	Extremely few	Forked
8. Manganese steel	Moderately large	45	White	White	Many	Fine, repeating
9. Stainless steel	Moderate	50	Straw	White	Moderate	Forked
10. Tungsten-chromium die steel	Small	35	Red	Straw*	Many	Fine, repeating*
11. Nitrided Nitralloy	Large (curved)	55	White	White	Moderate	Forked
12. Stellite	Very small	10	Orange	Orange	None	
13. Cemented tungsten carbide	Extremely small	2	Light Orange	Light Orange	None	
14. Nickel	Very small**	10	Orange	Orange	None	
15. Copper, brass, aluminum	None				None	

† Figures obtained with 12" wheel on bench stand and are relative only. Actual length in each instance will vary with grinding wheel, pressure, etc. *Blue-white spurts. **Some wavy streaks.

Figure 201. Table of spark test characteristics of alloy steels
(Courtesy of: Norton Company)

244. Miscellaneous Tests for Alloy Steels

The color test, ring test, magnetic test, fracture test, and the chip test are all applicable to alloy steels; perhaps the easiest one is the color test. The different alloy constituents tend to add color to the metal, which in certain compositions is very noticeable and characacteristic.

Stainless steels, for example, have a distinct tinge, or color, which sets them apart from the other steel alloys. Several of the metals are magnetic, whereas others are not; and segregation can be accomplished to a certain extent by using this test. The chip test is not used extensively for identifications because of the similarity in results of practically all these metals. However, some of these alloys are considerably harder than others, and the chip test will bring this out quite clearly.

The ring or metallic sound of the metal is another test which can be applied to these different alloys with accuracy. However, it is recommended that the others be relied upon.

245. Chemical Tests for Alloy Steels

There is no doubt that chemical tests will be used to identify the various steel alloys much more frequently than any other test. The alloys are identified by chemical reactions much more accurately and easily than by any other method. The application of different etching acids brings out the color of the alloy, or reacts with the alloys in the metal to the extent that they may be readily identified.

The method is as follows: A chemical test rack, holding bottles which contains the test chemicals, is set up in the shop. These chemicals are listed as having the property of acting upon the different metals with different results. Perhaps one chemical will react with only one of the different alloy metals, or the chemical may react with more than one bringing out different results, such as color and speed of reaction.

246. S.A.E. Numbering System

The Society of Automotive Engineers has long been a leader in standardizing in the automotive field. Because automobiles were the first to use steel of all kinds, the Society has developed a numbering system for identifying practically all steels. The code is based on a number of four digits, i.e., 2115. The first digit 2 classifies the steel, the number 2 representing nickel steels.

The list of steels is as follows:

1000 Carbon Steels

2000 Nickel Steels
3000 Nickel-Chromium Steels
4000 Molybdenum Steels
5000 Chromium Steels
6000 Chromium-Vanadium Steels
7000 Tungsten Steels
9000 Silicon Manganese Steels

Some special divisions are as follows:

30000 and 51000 are corrosion and heat-resisting steels
30000 Nickel Chromium Steels
51000 Chromium Steels

1100 are special, sulphus-carbon steels that have free cutting properties.

The second digit 0200 represents the per cent of the alloy metal in the steel, i.e., 2115 represents 1.25 to 1.75% nickel.

The last two digits represent the carbon content of the metal in points, i.e., .15 to .25% carbon. *Figure 202* is a table of sample S.A.E. steels.

247. Non-Ferrous Metals

Non-ferrous metals are all metals not containing iron (ferrous). This field includes copper, brass, bronze, aluminum, white metal, solder, stellite, die castings, lead, zinc, and nickel.

248. Copper

Copper is a chemical element of the metal family and is very popular because of its electrical conductivity and its ability to resist corrosion. Copper melts at a temperature of approximately 1,980° F. which is higher than the melting temperature of gold, and somewhat lower than the melting temperature of cast iron. *Figure 203*. Manufacturing processes are such that commercial copper usually contains sulphur, phosphorus, and silicon as its impurities. Each of these impurities has a tendency to make the copper more brittle and to reduce its weldability. However, a very small amount of phosphorus in copper is an aid to the welding of the metal, because of the dissolving property that the phosphorus has for copper oxides, permitting it to act as a flux. Most copper has a reddish brown color.

The only copper recommended for fusion purposes is deoxidized copper. This copper has had a very small amount of silicon added to it, which has the property of dissolving whatever cupric oxides are present in the metal. Enough silicon is added to the copper dur-

ing its manufacturing so that an excess is left in the copper after the deoxidizing action takes place. If this amount is too much, as mentioned above, the copper tends to become brittle.

Another feature of copper, which is typical of practically all-non-ferrous metals, is its behavior called "hot shortness." As copper is heated to its melting temperature, the copper becomes very weak at a certain temperature; then the slightest shock or weight will tend

STEELS

CHEMICAL COMPOSITIONS

SAE Standard

(Courtesy of: Society of Automotive Engineers)

The composition limits of SAE steels apply to the steels as delivered to the purchaser. The Iron and Steel Division has not approved any chemical tolerances beyond these limits.

CARBON STEELS

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus Max.	Sulfur Max.
1010	....	0.05-0.15	0.30-0.60	0.045	0.055
1015	....	0.10-0.20	0.30-0.60	0.045	0.055
X1015	....	0.10-0.20	0.70-1.00	0.045	0.055
1020	....	0.15-0.25	0.30-0.60	0.045	0.055
X1020	....	0.15-0 25	0.70-1.00	0.045	0.055
1025	....	0.20-0.30	0.30-0.60	0.045	0.055
....	X1025	0.20-0.30	0.70-1.00	0.045	0.055
1030	....	0.25-0.35	0.60-0.90	0.045	0.055
1035	....	0.30-0.40	0.60-0.90	0.045	0.055
1040	....	0.35-0.45	0.60-0.90	0.045	0.055
1045	....	0.40-0.50	0.60-0.90	0.045	0.055
1050	....	0.45-0.55	0.60-0.90	0.045	0.055
1055	....	0.50-0.60	0.60-0.90	0.040	0.055
1060	....	0.55-0.70	0.60-0.90	0.040	0.055
....	1065	0.60-0.75	0.60-0.90	0.040	0.055
....	X1065	0.60-0.75	0.90-1.20	0.040	0.055
1070	....	0.65-0.80	0.60-0.90	0.040	0.055
1075	....	0.70-0.85	0.60-0.90	0.040	0.055
1080	....	0.75-0.90	0.60-0.90	0.040	0.055
1085	....	0.80-0.95	0.60-0.90	0.040	0.055
1090	....	0.85-1.00	0.60-0.90	0.040	0.055
1095	....	0.90-1.05	0.25-0.50	0.040	0.055

Figure 202. Typical SAE metal composition numbers

Figure 202. Continued

FREE CUTTING STEELS

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus Range	Sulfur Range
1112	....	0.08-0.16	0.60-0.90	0.09-0.13	0.10-0.20
X1112	....	0.08-0.16	0.60-0.90	0.09-0.13	0.20-0.30
1115	....	0.10-0.20	0.70-1.00	0.045 max.	0 10-0.20
X1314	....	0.10-0.20	1.00-1.30	0.045 max.	0.10-0.20
X1315	....	0.10-0.20	1.30-1.60	0.045 max.	0.10-0.20
X1330	....	0.25-0.35	1.35-1.65	0.045 max.	0.10-0.20
X1335	....	0.30-0.40	1.35-1.65	0.045 max.	0.10-0.20
X1340	....	0.35-0.45	1.35-1.65	0.045 max.	0.10-0.20

MANGANESE STEELS [1]

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.
1330	....	0.25-0.35	1.60-1.90	0.040	0.050
1335	....	0.30-0.40	1.60-1.90	0.040	0.050
1340	....	0.35-0.45	1.60-1.90	0.040	0.050
...	1350	0.45-0.55	1.60-1.90	0.040	0.050

NICKEL STEELS [1]

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Nickel Range
2315	....	0.10-0.20	0.30-0.60	0.040	0.050	3.25-3.75
2330	....	0.25-0.35	0.50-0.80	0.040	0.050	3.25-3.75
2340	....	0.35-0.45	0.60-0.90	0.040	0.050	3.25-3.75
2345	....	0.40-0.50	0.60-0.90	0.040	0.050	3.25-3.75
....	2515	0.10-0.20	0.30-0.60	0.040	0.050	4.75-5.25

Figure 202. Continued

NICKEL CHROMIUM STEELS [1]

SAE No.		Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Nickel Range	Chromium Range
Primary	Secondary						
....	3115	0.10-0.20	0.30-0.60	0.040	0.050	1.00-1.50	0.45-0.75
3120	....	0.15-0.25	0.50-0.80	0.040	0.050	1.00-1.50	0.45-0.75
....	3130	0.25-0.35	0.50-0.80	0.040	0.050	1.00-1.50	0.45-0.75
3135	....	0.30-0.40	0.50-0.80	0.040	0.050	1.00-1.50	0.45-0.75
3140	....	0.35-0.45	0.60-0.90	0.040	0.050	1.00-1.50	0.45-0.75
X3140	....	0.35-0.45	0.60-0.90	0.040	0.050	1.00-1.50	0.60-0.90
3145	....	0.40-0.50	0.60-0.90	0.040	0.050	1.00-1.50	0.45-0.75
3150	....	0.45-0.55	0.60-0.90	0.040	0.050	1.00-1.50	0.45-0.75
....	3215	0.10-0.20	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
....	3220	0.15-0.25	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
....	3240	0.35-0.45	0.30-0.60	0.040	0 050	1.50-2.00	0.90-1.25
....	3245	0.40-0.50	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
....	3250	0.45-0.55	0.30-0.60	0.040	0.050	1.50-2.00	0.90-1.25
3312	....	max. 0.17	0.30-0.60	0.040	0.050	3.25-3.75	1.25-1.75
....	3415	0.10-0.20	0.30-0.60	0.040	0.050	2.74-3.25	0.60-0.95

[1] Silicon range of all SAE basic open hearth alloy steels shall be 0.15-0.30. For electric and acid open hearth alloy steels, the silicon content shall be 0.15 minimum

MOLYBDENUM STEELS [1]

SAE No.		Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Chromium Range	Nickel Range	Molybdenum Range
Primary	Secondary							
X4130	.....	0.25-0.35	0.40-0.60	0.040	0.050	0.80-1.10	....	0.15-0.25
4140	.....	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10	....	0.15-0.25
4150	.....	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10	....	0.15-0.25
4320	.....	0.15-0.25	0.40-0.70	0.040	0.050	0.30-0.60	1.65-2.00	0.20-0.30
X4340	.....	0.35-0.45	0.60-0.90	0.040	0.050	0.60-0.90	1.65-0.90	0.20-0.30
4615	.....	0.10-0.20	0.40-0.70	0.040	0.050	.....	1.65-2.00	0.20-0.30
4620	.....	0.15-0.25	0.40-0.70	0.040	0.050	.....	1.65-2.00	0.20-0.30
4540	.....	0.35-0.45	0.50-0.80	0.040	0.050	.....	1.65-2.00	0.20-0.30
4815	.....	0.10-0.20	0.40-0 60	0.040	0.050	.....	3.25-3.75	0.20-0.30
4820	.....	0.15-0.25	0.40-0.60	0.040	0 050	....	3.25-3.75	0.20-0.30

Figure 202. Continued

CHROMIUM STEELS [1]

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Chromium Range
5120	...	0.15-0.25	0.60-0.90	0.040	0.050	0.60-0.90
5140	. .	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10
5150	. .	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10
52100	...	0.95-1.10	0.20-0.50	0.030	0.035	1.20-1.50

CHROMIUM VANADIUM STEELS [1]

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Chromium Range	Vanadium Min.	Vanadium Desired
....	6135	0.30-0.40	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18
6150	....	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10	0.15	0.18

SILICON MANGANESE STEELS

SAE No. Primary	SAE No. Secondary	Carbon Range	Manganese Range	Phosphorus, Max.	Sulfur, Max.	Silicon Range
9250	....	0.45-0.55	0.60-0.90	0.040	0.050	1.80-2.20
9260	....	0.55-0.65	0.60-0.90	0.040	0.050	1.80-2.20

[1] Silicon range of all SAE basic open hearth alloy steels shall be 0.15-0.30. For electric and acid open hearth alloy steels, the silicon content shall be 0.15 minimum.

CHROMIUM NICKEL AUSTENITIC STEELS—NOT CAPABLE OF HEAT TREATMENT

SAE No.	AISI[1] Type	Carbon	Manganese, Max.	Silicon, Max.	Phosphorus	Sulfur	Chromium Range	Nickel Range	Molybdenum	Selenium Range	Titanium or Columbium
30615 (type 1)	303	0.15 Max.	2.00	0.75	0.04 Max.	0.18-0.35	17.00-20.00	7.00-10.00	0.60 Max.	....	....
30615 (type 2)	303	0.15 Max.	2.00	0.75	0.12-0.17	0.04 Max.	17.00-20.00	7.00-10.00	0.60 Max.	0.15-0.35	....
30705	321, 347	0.08 Max.	2.50	1.50	0.03 Max.	0.03 Max.	17.00 Min.	8.00 Min.	....	....	0.40[2] Min. 0.70[3] Min.
30805	316	0.10 Max.	2.50	0.75	0.03 Max.	0.03 Max.	16.00-18.00	10.00-14.00	2.00-3.00	....	....
30905	304	0.08 Max.	2.00	0.75	0.03 Max.	0.03 Max.	18.00-20.00	8.00-10.00	....	....	....
30915	302	0.08-0.15	2.00	0.75	0.03 Max.	0.03 Max.	17.00-20.00	7.00-10.00	....	....	....

STAINLESS CHROMIUM IRONS

SAE No.	AISI[1] Type	Carbon	Manganese, Max.	Silicon, Max.	Phosphorus, Max.	Sulfur	Chromium Range	Nickel Range	Molybdenum, Max.
51210	410	0.08-0.15	0.60	0.50	0.03	0.03 Max.	11.50-13.00	....	....
51310	414	0.08-0.15	0.60	0.50	0.03	0.03 Max.	11.50-13.50	1.25-2.00	....
51335	420	0.25-0.40	0.60	0.50	0.03	0.03 Max.	12.00-14.00	....	....
X51410	416	0.13 Max.	1.20	0.75	0.04	0.18-0.35	12.00-14.00	....	0.60
51710	430	0.12 Max.	0.60	0.50	0.03	0.03 Max.	16.00-18.00	....	....

[1] American Iron and Steel Institute.
[2] Minimum if Titanium is used.
[3] Minimum if Columbium is used.

Figure 202. Typical S.A.E. metal composition numbers
(Courtesy of: Society of Automotive Engineers)

to distort the metal very firmly supported and firmly clamped to prevent distortion while the metal is passing through this temperature. The approximate point of this hot shortness is a medium cherry red color in the metal.

Metal	Melting Temperatures	
	°F.	°C.
Aluminum	1217	659
Arruco Iron	2795	1535
Bronze 90 Cu, Bronze 10 Sn	1562-1832	850-1000
Brass 90 Cu 10 Zn	1868-1886	1020-1030
Brass 70 Cu 30 Zn	1652-1724	900-940
Copper	1981	1083
Iron	2786	1530
Lead	621	327
Mild Steel	2462-2786	1350-1530
Nickel	2646	1452
Silver	1761	960
Tin	450	232
Zinc	786	419

Figure 203. Melting temperatures of common metals

249. Brass

Brass is an alloy of copper and zinc, although small amounts of other metals are frequently added. The most common of these is a small percentage of tin (1-5 per cent). A very common alloy of copper and zinc to form brass is 70 per cent copper and 30 per cent zinc. This metal is used principally because of its acid-resistance qualities, because of its appearance (an opaque yellow), and because it is a very good soldering alloy. It behaves very similarly to copper, but it is not so critical in its oxidation or in its brittleness when impurities are added to it. The amount of the zinc in the alloy can vary from 10 to 40 per cent. There are two common types of brass: one type is called machine brass, which contains 32 to 40 per cent zinc, while red brass contains from 15 to 25 per cent zinc. Some other metals which are added to make a triple alloy in addition to the tin mentioned above are manganese, iron, and lead.

250. Bronze

Bronze is an alloy of copper and tin. A common ratio is 90% copper and 10% tin. It behaves very much like brass when being welded. Generally speaking, one uses the same filler rod and the

same flux for both. Its color is deeper than brass, that is, it tends more to the copper color.

251. Aluminum

Aluminum is an element of the metal family known for its electrical conductivity, its heat conductivity, its resistance to corrosion and its light weight. It is obtainable either in the rolled or cast form and may be combined with many other metals to form numerous alloys. In its pure form the metal has a white color, and is very ductile in the rolled aluminum sheet form; but cast aluminum is very brittle. The strength of the pure metal is considerably less than that of steel and its melting temperature is approximately 1,220° F. This metal also has a critical point called "hot shortness" and for that reason, must be carefully mounted when being welded. An element which may be added to aluminum to decrease its "hot shortness" is silicon.

Due to the activity of the metal, aluminum oxidizes very readily upon being heated. This oxide melts at 5,000° F., and therefore chemicals must be used to dissolve them. Also the oxide is more dense than the molten metal and settles into a puddle, causing a porous weld. Therefore, special fluxes must be used at all times during the welding process.

Another feature of aluminum which adds to the difficulty of welding is that it does not change in color before it reaches the melting temperature. In other words, the metal upon being heated maintains the same color, but when reaching the melting point, it suddenly collapses. The operator can determine the melting temperature of the metal, when welding aluminum, only by using the filler rod and scratching the surface to reveal any softening. If one uses a blue, cobalt welding-goggle-lens, the weld can be much better observed than with more dense goggles.

Aluminum sheet metal may be obtained in several qualities and grades. The purest commercial aluminum contains 99½ per cent aluminum, while the more popular commercial grades contain 99 per cent aluminum. Two metals which are added to aluminum to increase its desirable physical qualities are manganese and magnesium. Amounts of these are relatively small, varying from 1 to 5 per cent. Special alloys of aluminum, such as duralumin, are becoming very popular for aircraft work. Duralumin is noted for its high tensile strength, but it is very difficult to weld satisfactorily. Any mechanical working of it while it is cold also tends to increase its brittleness.

252. Stellite and Other Hard Surface Metals

Research has succeeded in producing alloys of metals having the property of extreme hardness. One of the most popular of these alloys is Stellite, which is a non-ferrous alloy, consisting principally of cobalt, chromium, and tungsten. This metal is extremely hard, but it is also very brittle. Its best application, therefore, is as a thin coating on metal of a more ductile nature. This combination produces a long wearing surface and also one of great strength.

Another metal known for its hardness and wear resistance qualities is "Hascrome," which is an alloy of chromium, magnesium, and iron. This alloy has the special property of resisting severe impact, and also serves very satisfactorily as a hard-wearing surface.

Another alloy used for hard-surfacing is Haystellite, an alloy of tungsten and carbon. The best characteristic of this alloy is its resistance to abrasion. However, its extreme brittleness requires that it be mounted on a more ductile metal to prevent it from chipping or cracking under impact.

253. Review Questions

1. How do properties of steel change as carbon content increases?
2. What is the highest carbon content of steel?
3. May cast iron be heat-treated?
4. What are the different forms of cast iron?
5. What is the difference between the various forms of cast iron?
6. What is meant by an alloy steel?
7. What properties do alloys give to steel?
8. What is meant by a low-carbon-alloy steel?
9. What characteristic does Tungsten Steel have?
10. What is stainless steel?
11. May stainless steel and low-carbon-alloy steel be welded?
12. Name some methods of identifying metals.
13. What is meant by the blow torch test?
14. What is meant by the critical temperature of a metal?
15. What is meant by the fracture test?
16. Is there a difference in the appearance of copper, bronze, and brass?
17. What is the carbon range of steel that responds to heat treatment?
18. What is the tensile strength of 25 point carbon cold roll steel?
19. What is the spark test?
20. What is the explanation of the variation in sparks?
21. What method is used to secure accurate analysis of a metal"

CHAPTER XVII

HEAT TREATMENT OF METALS

The heat treatment of metals is a very involved subject. The welder is particularly interested because he must know what welding does to the heat treatment of a metal and the consequent effect on the physical properties of the metal. One must also know what heat treatments to use to bring the metal back to possess as nearly as possible its original properties. The most common application of heat treating in a welding shop is annealing to relieve the metal of internal stresses and strains, caused by the expansion and contraction during welding, and to improve the properties of the metal in the weld. Most structural welding involves only the knowledge of how a metal may be annealed. It is in job welding, involving the repair of broken parts, that an extensive and accurate knowledge of all phases of heat treating is most needed.

254. The Purposes of Heat Treatment

All metals can be heat treated. Some metals are affected very little, but some, particularly most steels, are greatly affected. Heat treating may serve the following purposes: (1) to soften metals (annealing), (2) to relieve internal stresses and strains (annealing), (3) to harden metals (usually rapid cooling), (4) to refine the structure of the metal (remove brittleness), and (5) to temper the metal (make some parts of the metal hard, other parts tough).

255. Characteristics of Steel

Inasmuch as steel is the most common industrial metal, and because it has the greatest variety of heat treatments, it requires the most complete discussion. Steel may be obtained in a variety of types, depending upon the carbon content and alloying metals. *Figure 204.* The family of steels starts with low-carbon steel (almost wrought iron); as the carbon content increases, the steel becomes harder, stronger, and more brittle until approximately 2.25% carbon is reached. Above 1.7% to 2.25% carbon, the combination is called cast iron.

256. Crystalline Structure

Practically all heat treatments deal with the crystalline structure of steel, or the grain size. It is also concerned with combinations of iron and carbon, and with the distribution of iron carbide in the

Approximate Carbon Content of Steels

Article	Carbon Content
Axles	.40
Boiler Plate	.12
Boiler Tubes	.10
Castings, Steel	....
Case-hardening Steel	.12
Chain	Min.
Cold Chisels	.75
Cold-rolled Steel	....
Concrete Reinforcing Bars	....
Metal Files	1.25
Forgings	.30
Gears	.35
Hammers	.65
Lathe Tools	1.10
Machinery Steel	.35
Metal Tools	.95
Nails	.10
Pipe, Steel	.10
Piano Wire	.90
Rails	.60
Rivets	.05
Set Screws	.65
Saws for Wood	.80
Saws for Steel	1.55
Shaft	.50
Springs	1.00
Steel for Stamping	.90
Tubing	.08
Wire, Soft	.10
Wood Cutting Tools	1.10
Wood Screws	.10

Figure 204. Steels and their uses

metal. In 10 point carbon steel, which contains 1/10 of 1% carbon, all of the carbon is in chemical combination with iron, forming iron carbide, Fe_3C. There is considerable free iron remaining which in metallurgy is called ferrite. Because of the large amount of ferrite, the steel cannot be hardened; the only heat treatment possible is to

alter the grain structure and size. Heating the steel to the critical temperature does not affect the steel very much because it is the status of the iron carbide chemical which determines the hardness. The iron carbide, mixed in various proportion with ferrite, gives several combinations of hardness and brittleness, depending upon various heat treatments. These hardness levels have been given several names. In the order of their hardness the steels are listed as follows:

(1) Austenite
(2) Martensite
(3) Troostite
(4) Sorbite
(5) Pearlite

Figure 205. Pearlite steel (magnified 1000X)
(Courtesy of: General Motors Corporation)

These are various forms of iron carbide in combination with ferrite. The various forms are obtained by the following steps:

(1) heating
(2) quenching
(3) drawing
(4) tempering

Eighty-five point crystalline steel has the correct amount of carbon to form steel that has the lowest critical temperature. This is called the "eutectic point." When properly heat-treated, the whole structure of this steel becomes pearlite. Pearlite is a steel which under the microscope has alternate layers or rows of iron carbide and ferrite. These beads look very similar to a fingerprint printed with black ink on white paper. *Figure 205.* This steel also is the only steel that has just one critical temperature.

If the steel sample is heated to 1,250° F. and then quenched in very cold brine, austenite is formed. If heated to 1,250° F. and quenched in cold water, martensite is formed. If heated to its

critical temperature and quenched in oil, troostite is formed. If heated to 1,250° F. and quenched in a molten metal bath, sorbite and pearlite are formed. The above steps show that the rapidity of cooling affects the distribution and clustering of the iron carbide. Quenching, therefore, has much to do with the type of steel one desires.

To obtain the above results in another manner, proceed as follows: Heat the eighty-five point carbon steel to 1,250° F.; by quenching in cold brine, austenite is formed. If one desires Martensitic steel, reheat the sample to 400° F. and cool. If troostite is desired, reheat the sample to 600° F. and troostite is formed. Or reheat to 800° F. and cool; then sorbite is formed. Or reheat to 1,000° F. and cool; pearlite is formed. The temperatures to which these various forms of steel are heated overlap, so that in many cases, one may have a steel which is part sorbite and part troostite, or part sorbite and part pearlite.

257. Annealing Steel

The term annealing is a very common term in heat-treating, and includes several types of heat-treating operations. Generally speaking, annealing is considered to be that type of heat treatment which refines the grain and leaves the metal in a soft condition. An annealing operation may be performed for several reasons: (1) To enable one to work the metal cold. (2) To make the steel machinable. (3) To relieve the internal stresses and strains produced while the metal was being shaped or welded.

The general procedure for annealing most steels is as follows: (1) Heat the steel slightly above the critical temperature. (2) Cool the steel as slowly as possible.

If the grain size is of no importance, one does not have to be careful of the exact temperature to which the steel is being heated.

Steel, upon being heated to the critical temperature, changes its crystalline structure and reaches its most defined condition at its lowest critical temperature. However, if the steel is heated above this temperature, the grain size starts to grow; and the grain size becomes larger as the temperature rises. The steel will retain the size of the maximum crystalline structure reached, no matter what rate of cooling is used. This is particularly important in welding because both the weld metal and the metal adjacent to the weld are heated considerably above the critical temperature.

Upon cooling a weld, regardless of the speed of cooling, the crystalline structure in the weld, and in the steel adjacent to the weld,

will be extremely large and both have very poor physical properties. Two methods may be used to remedy this condition. (1) Pound the metal with a hammer as it is cooling. This will refine the grain structure by distortion. (2) Allow the metal to cool to room temperature; reheat to the critical temperature of the metal and then allow it to cool slowly.

The latter method is preferred. Industries with the facilities for doing so really put the whole steel structure, which has been welded, in an annealing furnace; thus the whole structure is annealed instead of just the weld and the parts adjacent to it.

258. Hardening Steel

Steel may be hardened by heat treatment, but certain ranges of carbon content are also required to obtain any degree of hardness. It is a common practice also to desire a refinement of the grain structure along with the hardness. Steels of less than 50 point carbon content cannot be successfully hardened by heat treatment. Steels above 170 point carbon content are also difficult to harden by heat treatment. Within these extremes one finds a good range of carbon content, enabling one to obtain almost any degree of hardness by using the proper carbon content and the proper heat treatment.

Generally speaking, to harden a steel specimen in this range of carbon content, one must heat the steel to its critical temperature and then cool rapidly. *Figure 206.* As mentioned in a previous paragraph, the rapidity of cooling determines to a great extent the hardness and brittleness of the metal. Cold brines, cold water, molten metal baths, and air are used as mediums for cooling the metal rapidly. The water cooling and the brine cooling result in extreme brittleness along with hardness; but air cooling and molten-metal-bath cooling tends to relieve much of the brittleness. The hardness of the metal seems to depend upon the distribution and structure of the iron carbide throughout the steel. When cooled rapidly, there is little opportunity for the iron carbide to separate or segregate.

259. Tempering Steel (Drawing)

As stated in the above paragraph, quenching a steel sample in a molten-metal bath will produce a hard metal without too much brittleness. However, although this method is satisfactory, it is not the best. More practical and much more effective is a method called drawing the hardness. By reheating the steel sample to some tem-

perature between 400° F. and 1000° F., after the hardening operation, one may relieve much of the brittleness in the steel; and just as important, most of the internal stresses and strains are relieved. Reheating the metal to 600° F. (blue color on the steel surface) is probably the most common drawing or tempering operation.

Percent Carbon	Temperature °F.	
	Full Annealing Critical Temperature	Commercial Annealing
.10	1675-1760	
.20	1625-1700	
.30	1560-1650	
.40	1500-1600	
.50	1450-1560	1020° F.
.60	1440-1520	to
.70	1400-1490	1200° F.
.80	1370-1450	
.90	1350-1440	
1.00	1350-1440	
1.10	1350-1440	
1.30	1350-1440	
1.50	1350-1440	
1.70	1350-1440	
1.90	1350-1440	
2.00	1350-1440	
3.00	1350-1440	
4.00	1350-1440	

Figure 206. A series of critical temperatures for various carbon steels

260. Tempering a Cold Chisel

A common tempering operation in any metal shop is the heat treatment of the cold chisel. Most cold chisels are made of approximately 80 point carbon steel and must have the following properties. The cutting edge must be extremely hard. The metal just back of the cutting edge must be hard and tough, not brittle. The body of the chisel and the adjacent, or hammering end, must be soft and ductile. To obtain these various properties from the same carbon content steel, one must heat treat it as follows: (1) Heat the cold chisel slowly up to its critical temperature (1350° F., cherry red). (2) Allow enough time for the body of the chisel to assume this temperature throughout its thickness; then quench the cutting edge of the chisel in cold water for approximately one inch of its length. (3) Wait until the end in the water turns dark;

then withdraw the chisel quickly from the water; the other end is still a cherry red temperature. (4) Heat from this cherry red end will now travel to the chilled cutting edge, reheating it slowly. With a small pad faced with emery cloth, polish the flat surfaces near the cutting end of the chisel. Be careful of burns. Now watch the polished surface carefully. As the heat from the shank of the chisel travels into this part, the polished surface will gradually change color. It will first become yellow, then brown; when the surface starts to turn purple, because of the oxidation of the metal as the temperature rises, it indicates the steel has been re-heated to approximately 600° F. Now quench the cutting edge in the water slowly; if the shank of the chisel has cooled beyond a cherry red, as it should do, the complete chisel may be immersed in a bucket of cold water.

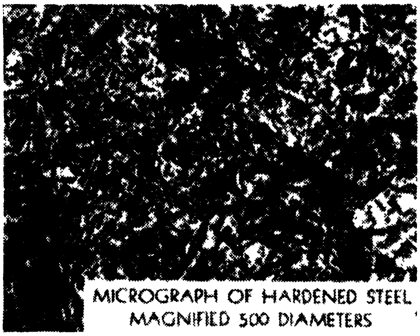


Figure 207. Hardened high carbon steel
(Courtesy of: General Motors Corporation)

If the timing is correct on the heat treatment, and if the original temperature is not too high, the chisel will have a hard cutting edge, with a fairly hard and tough body and finally a soft ductile shank or hammer end. In case the original temperature was too high, the chisel will be brittle and will crack easily because of the large crystalline structure, and the cutting edge will be too hard and will chip off as it is being used. If the cutting edge was re-quenched before it should have been, the cutting edge will be hard and the chisel will be worthless. If the shank of the chisel is quenched too soon (before its color has become a dark red), the shank will be too hard and brittle and will crack when being used. One may well point out here that a chisel with brittle qualities is an extremely dangerous tool because the flying particles of metal may inflict injuries.

261. Heat Treating Tool Steels

There are several classifications of tool steels. The cold chisel, mentioned above, usually has a carbon content of 75 point to 85 point carbon. It is considered a lower grade tool steel, and is similar to all tool steels having between 50 point carbon and 100 point carbon. To anneal this steel one should heat the 50 point carbon steel to 1400° F. and cool slowly. To anneal 85 point carbon steel, heat it to 1300° F. and cool it slowly. To anneal 100 point carbon steel, heat to 1450° F. To harden this range of steel, one must heat it to the temperature mentioned above and cool rapidly. *Figure 207.*

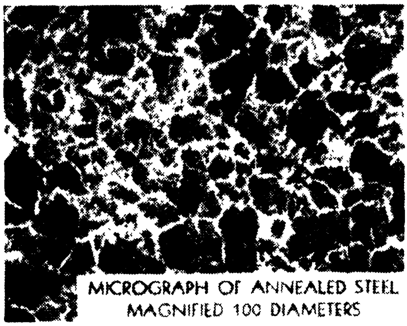


Figure 208. **Annealed high carbon steel**
(Courtesy of: General Motors Corporation)

To draw the tool steels mentioned above, one must heat them to the temperatures mentioned and then cool the sample rapidly. The sample must then be reheated to a temperature of 400° F. to 900° F. and cooled. The higher the temperature to which the sample is reheated, and the longer it is held at this temperature, the softer and more ductile the steel becomes. *Figure 208.*

Tool steels between 100 point carbon and 170 point carbon must be heated from 1350° F. to 1450° F. and cooled slowly to anneal. To harden, heat the samples to the same temperature and cool rapidly. To relieve the brittleness by drawing, heat the sample to the above temperature, cool rapidly, and then reheat to a temperature between 400° F. and 900° F. Most of these steels are not simple, iron-carbide steels, but are usually alloy steels. *Figure 209.*

262. Heat Treating Alloy Steels

The heat treatment of alloy steels is a rather difficult problem, because of the multiplicity of alloy metals, and the hundreds of

combinations of these alloy metals with the iron carbon steels. Alloy metals, generally speaking, lower the critical temperature of the iron carbide steel. Some alloy metals have a special influence on the characteristics of the heat treatment. For example, iron carbide steel, with manganese added to it as an alloying metal, will become a self hardening steel. If a sample of manganese steel is heated to its critical temperature (1350° F.) and cooled in air, the sample is as hard as an ordinary iron carbide steel sample quenched in cold water. Further, this alloy has the characteristic of main-

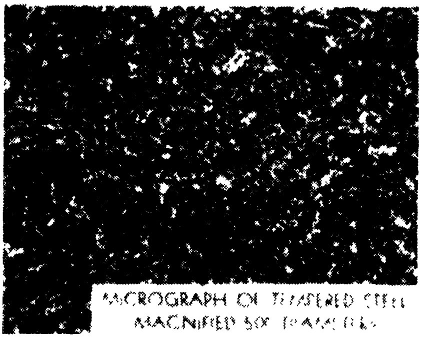


Figure 209. Tempered high carbon steel
(Courtesy of: General Motors Corporation)

taining its hardness at high temperatures. This makes it very adaptable as a metal cutting tool. Chromium-tungsten, high speed steel also has the property of maintaining hardness at a high temperature. It is difficult to anneal these steels because of the self hardening properties. In order to heat-treat these steels properly, one must obtain the exact percentage of the constituents in the steel; if possible, he must obtain the recommended process as set forth by the company which manufactures the steel.

263. Flame Hardening

One of the outstanding modern contributions to industry of the Oxy-Acetylene process has been the development of flame-hardening, which is being widely used today in many manufacturing operations. In many cases such as gears, shafting, connecting rods, and the like, it is very advisable to produce as hard a wearing surface as possible, and yet maintain the internal portion of the structure in a ductile and tough condition. The hard surface provides long wear and maintains an exact contour, while the tough interior insures withstanding shocks without breaking. Previous to the de-

velopment of the flame-hardening process, complicated heat treatments had to be performed with temperatures under extremely accurate control, and with exact timing. Any change in the size of the structure necessitates a complete, new experimental set-up to determine the proper conditions.

Flame-hardening has eliminated much of this in the flame hardening process. The article is heat treated and then drawn to produce a tough, ductile structure throughout. The surfaces to be hardened are then put in a flame-hardening machine. A multiple-tipped Oxy-Acetylene torch is passed over the surface to heat it very quickly to a high temperature. Following the flame a heavy stream of water is automatically fed to the surface, which quickly

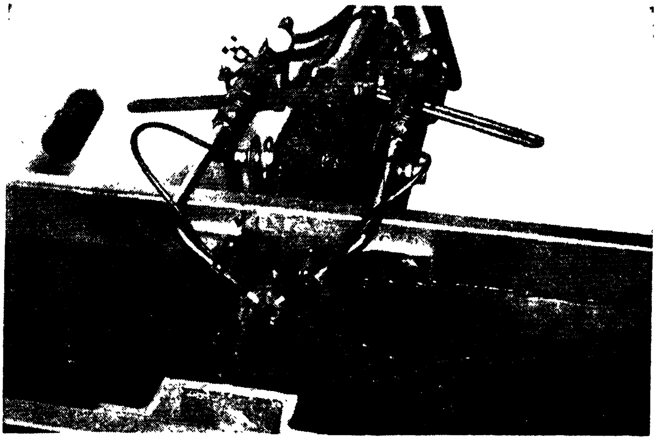


Figure 210. A flame hardening machine
(Courtesy of: Linde Air Products Company)

cools the entire surface. *Figure 210.* The depth of the hardness can be accurately controlled by the size of the tips and the speed of travel over the surface; and the degree of hardness can be accurately controlled by the temperature of the water acting as a cooling agent. This method has proved to be a rapid and economical means of hardening that is quickly adaptable to any type of structure. The application of the Oxy-Acetylene torch is becoming just as important to the metal industry as the use of the Oxy-Acetylene cutting torch.

264. Case Hardening

Another solution of the above problem of producing a metal article with a tough interior and a hard, accurate, hard-wearing sur-

face is known as case hardening. The fundamental plan of the process is to make the article out of low carbon steel. The machinery may, therefore, be done easily. The surfaces to be hardened are exposed to carbon at high temperatures. The high temperature iron will absorb some of the carbon, increasing the carbon content of the surface which may then be hardened by the simple heat treating process. This method is called the sherodizing process. Typical examples of this method are piston pins in all kinds of engines, cam-shafts in all types of engines, and many other articles. *Figure 212.* In case it is not desirable to case harden certain portions

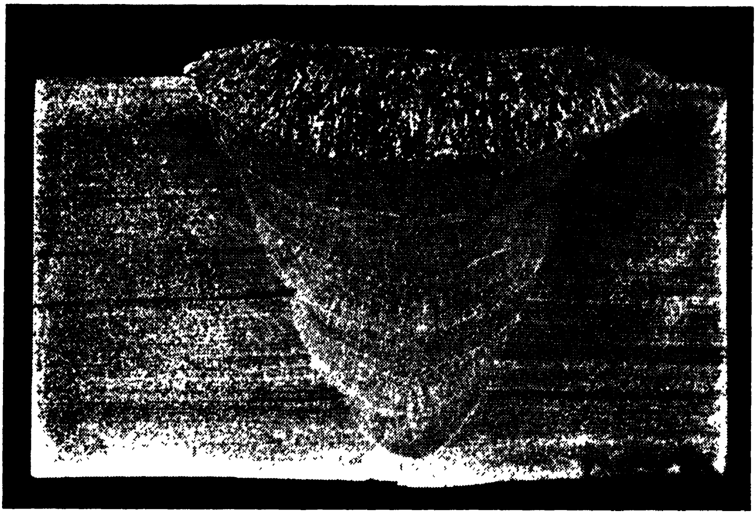


Figure 211. Cross section of an arc weld that was welded in several passes. The refined grain of the first passes shows the annealing effect of heat from the succeeding passes (etched)
(Courtesy of: General Electric Company)

of the article exposed to the carbon at high temperatures, these portions may be copper plated. Generally speaking, the carbon will penetrate into the steel to a depth of $\frac{1}{64}$ of an inch per hour. This depth will vary with the temperature, kind of carbon used, and the steel to be case hardened.

A cyanide bath may also be used to case harden steel, but the danger from the fumes makes its application limited. Thorough ventilation is imperative when using the cyanide salts.

To heat-treat a case hardened object one proceeds as follows: The steel is heated to the critical temperature and quenched, which produces a glass-hard exterior on those parts which have been exposed to the carbon bath. This also produces a refined grain-tough

interior which is of low carbon content affecting the strength and ductility of the interior extensively. The surface conditions are then drawn by reheating to a temperature between 400° F. and 900° F. *Figure 213.*

265. Heat Treating Cast Iron

As mentioned previously there are three forms of cast iron, namely, white cast iron, gray cast iron, and malleable iron. They

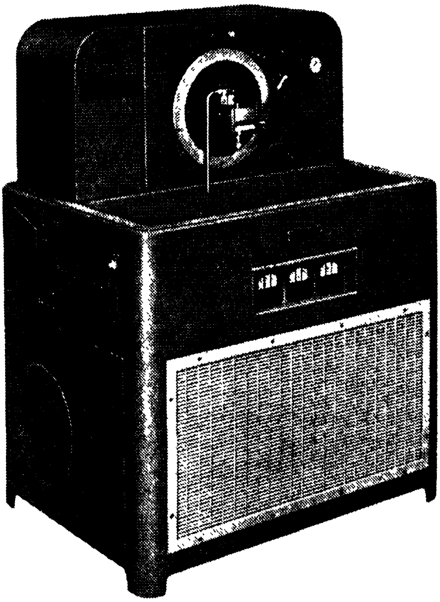


Figure 212. An induction heat treating furnace. This is a small single station heating and hardening unit
(Courtesy of: The Cleveland Crankshaft Company)

are all similar cast irons in reference to their carbon content and method of manufacture. They differ because of the heat treatments. White cast iron is formed by heating a cast iron sample to the critical temperature (1650° F. to 2088° F.) and cooling rapidly. This cast iron derives its name from the appearance of the fracture which is very white as a result of the carbon being in solution with the iron, forming cementite and pearlite.

If cast iron is heated to its critical temperature, and then cooled very slowly (in asbestos, in sand, or in the furnace) and slow change through the temperature ranges permits enough time for some of the excessive carbon to separate from the iron and form

microscopic flakes of graphite. When a sample of this type of cast iron is broken, the fracture has a grayish color because of the number of graphite flakes imbedded in the cast iron body.

White cast iron, because of the excessive amount of carbide, is not machinable; whereas gray cast iron, because of the presence of the graphite flakes and the reduction of the amount of carbide, is very easily machinable.

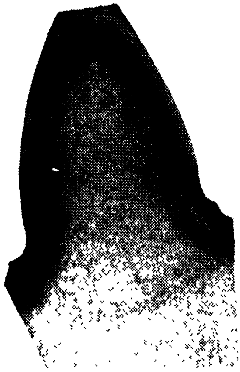


Figure 213. A sample of a case hardened steel gear tooth
(Courtesy of: General Motors Corporation)

Malleable iron is cast iron heat-treated to make it more ductile and more resistant to shock. This type of cast iron is formed by heating a casting to its critical temperature and cooling it very rapidly, thus forming white cast iron; then re-heat to a temperature between 1450° F. and 1650° F., and keep it at this temperature for 24 hours for each inch of casting thickness. Being maintained at this high temperature for this duration of time enables much of the carbon to separate slowly from the iron in the casting, forming globular carbon (spheroids of carbon or small microscopic pools of carbon surrounded by low carbon iron). After heat treatment at this high temperature for the proper length of time, the casting is cooled slowly.

By noting the above conditions for the production of malleable iron, one will readily realize that if a malleable casting is welded, the casting will lose all of its malleable qualities in the weld and in the vicinity of the weld. For this reason all malleable castings (recognized easily by a low-carbon spark on the surface and a cast-iron spark in the center) should be brazed, or bronze welded.

A special application of an effective heat treatment on cast iron is the heat treatment given to railroad car and street car wheels. These wheels are cast in a special mold which provides a special means of rapidly cooling the rim or periphery of the wheel; whereas the remainder of the wheel is cooled slowly. This produces a wheel that has a white cast iron rim (very hard) and a gray cast iron body that is not so readily fractured if subjected to shock.

266. Heat Treating of Copper

Copper becomes hard and brittle while being mechanically worked. However the metal can be made soft again by annealing. To anneal copper, it should be heated to a temperature between 700° F. and 900° F. and then cooled either rapidly or slowly. This heat treatment eliminates the fractured crystalline structure caused by the slipping of the original crystal on its slip bands and makes the copper soft, pliable, and ductile; it brings back its original ductile qualities.

One must be careful when heating the copper to its annealing temperature because, at approximately 900° F., copper undergoes a peculiar physical phenomenon or change, called "hot-shortness." At this temperature the copper suddenly loses its tensile strength; if not adequately supported or subjected to shock or strain, it may fracture very easily.

267. Heat Treating Aluminum

Aluminum is heat treated in a manner very similar to the copper mentioned above. As it also has the characteristic of hot shortness, one must be very careful when aluminum is passing through that temperature. Mechanical working also makes aluminum harder and much more brittle. This may be relieved by heating and cooling. The critical temperature is approximately the same as that of copper.

Just as copper has many alloys, so aluminum has a number of alloys, each of which has its own peculiar heat treatment in order to bring out the best properties of the alloy. One of the most famous aluminum alloys, and one that has a very conspicuous heat treatment, is known as duralumin. This is an alloy consisting principally of aluminum; it also contains copper, nickel, and iron. The simplest mechanical working to which duralumin is subjected makes it very brittle. When subjected to welding, it loses all its outstanding characteristics. After being welded, it is very hard to return duralumin to its original condition. In order to regain its strength

a portion of its heat treatment properties consists of age hardening the duralumin. After being heated to the critical temperature and being cooled slowly for annealing, the duralumin sample is then reheated to approximately 450° F. (salt bath) and maintained at this temperature until the temperature is uniform throughout the article. The sample is then cooled slowly in the air. After being tested duralumin slowly becomes harder (age hardening) with time at ordinary temperatures.

268. Review Questions

1. What is annealing?
2. What is hardening?
3. What is tempering?
4. Why must aluminum be well supported when being welded?
5. What causes stresses and strains in a weld?
6. What carbon steel has the lowest critical temperature point?
7. What may be done to relieve the strains in a weld without reheating it?
8. How is a steel sample made both hard and tough?
9. Why must one be careful of how long a sample is heated when heat treating it?
10. Explain "air-hardening" steel.
11. How may gray iron be turned into white cast iron?
12. May a cold chisel be correctly heat treated by only heating it once?
13. If a large article is heated in a gas furnace to anneal it, where is the best place to cool it?
14. How may a sample of brittle copper be annealed?
15. What is meant by the term "drawing"?

CHAPTER XVIII

THE WELDING SHOP

When fusion welding was originated the equipment and the work were considered an accessory to shops of other kinds such as the blacksmith shop, the automobile repair shop, and the metal fabricating shop. As the industry became more important, welding became a part of a separate welding department. Later independent establishments were formed which specialized in the repair of welding equipment. There are, therefore, three types of welding shops in existence at the present time:

1. The welding shop, or department, attached to some factory or manufacturing establishment.
2. The independent welding shop jobbing which specializes in repairing and fabricating metal structures by the various methods of welding.
3. The welding equipment repair shop which overhauls and repairs welding equipment for the above two shops.

The first two shops, however, do fundamentally the same thing; and though the first one may specialize in a certain type of welding, the equipment, tools, supplies, and the general plan for both are similar.

269. Welding Shop Equipment

The kind of, the number, and the size of the equipment used in the welding shop depends considerably upon the kind of work handled. Some of the more common equipment used is as follows:

1. Oxy-acetylene Welding Station
2. DC Arc Welding Station
3. AC Arc Welding Station
4. Resistance Welding Machine
5. Pre-heating Furnace
6. Over-head Crane
7. Forge
8. Benches, Vises, and Anvils
9. Jigs and Fixtures
10. Power drills and grinders
11. Sand blasting equipment

270. Oxy-Acetylene Station

The oxy-acetylene welding station may be divided into two general classes, the station for welding and the station for cutting. More than one station may be available for either or both of these; and in case more than one station is used, manifolds may be used for the gases. The details of construction of the oxy-acetylene welding equipment is described in Chapter 2. The station consists of the gas tanks, the regulators, the hose, the torch, and a bench upon which the work to be welded is assembled. It is recommended that at least one of the oxy-acetylene stations should be a portable apparatus to enable it to be moved around the shop. *Figure 214.*

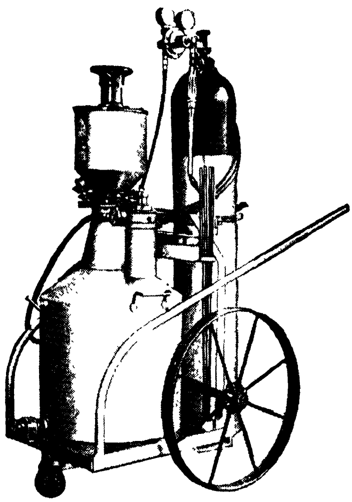


Figure 214. A portable oxy-acetylene welding station with an acetylene generator
(Courtesy of: Modern Engineering Company)

The accessories of an oxy-acetylene welding station should be attached to the station, or should be kept in a portable kit to save time and effort in assembling the necessary apparatus to do a welding job. These accessories include leather gloves, pliers, welding goggles, a lighter, and wrenches. The special wrenches needed for adjusting and operating the welding station are best handled by attaching them to the welding station rack, or to the welding bench near the station by means of chains.

271. Arc Welding Station

The arc welding station, either AC or DC, should have the following equipment: an enclosed booth to protect the other men in the

shop from the harmful rays radiating from the arc, a bench upon which the work is to be assembled and welded, a ventilating fan to remove the fumes from the booth to the outside of the building before they can be dissipated into the whole of the shop. The booth should be painted on the inside with a special arc ray absorbing paint. *Figure 215.* This paint is of a gray white color and has the

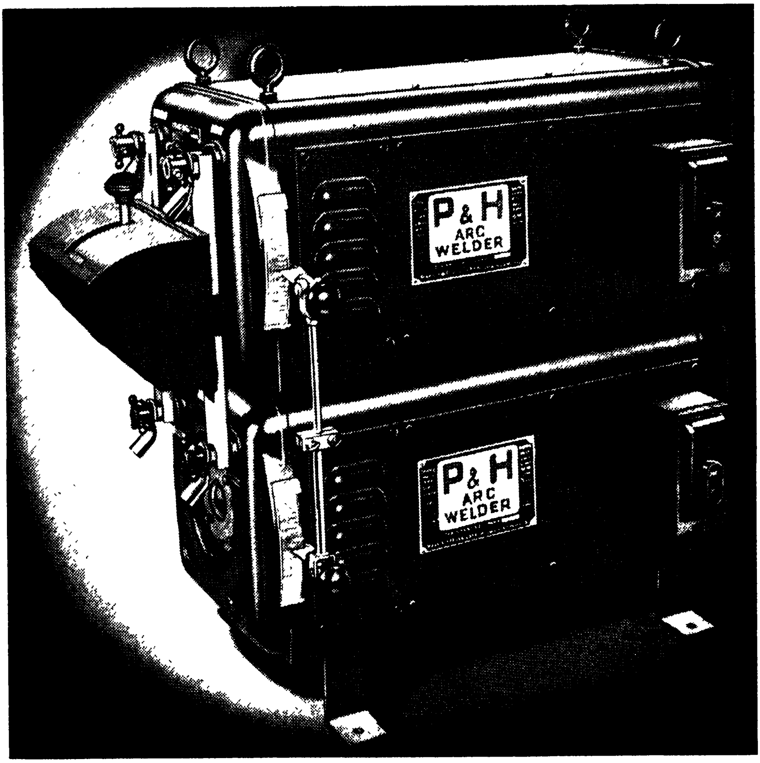


Figure 215. A dual arc welding installation
(Courtesy of: Harnischfeger Corporation)

peculiar property of absorbing and not reflecting the infra-red and ultra-violet rays. This eliminates much of the flashing, which would otherwise interfere with the other workmen in the shop. It also eliminates much of the glare from the reflections which coming sometimes from around the back of the welder's shield, or helmet, interferes with his vision, and hurts his eyes.

272. Resistance Welding Machine

Although not generally used at present, more and more shops are purchasing and using resistance welders. The two most popular

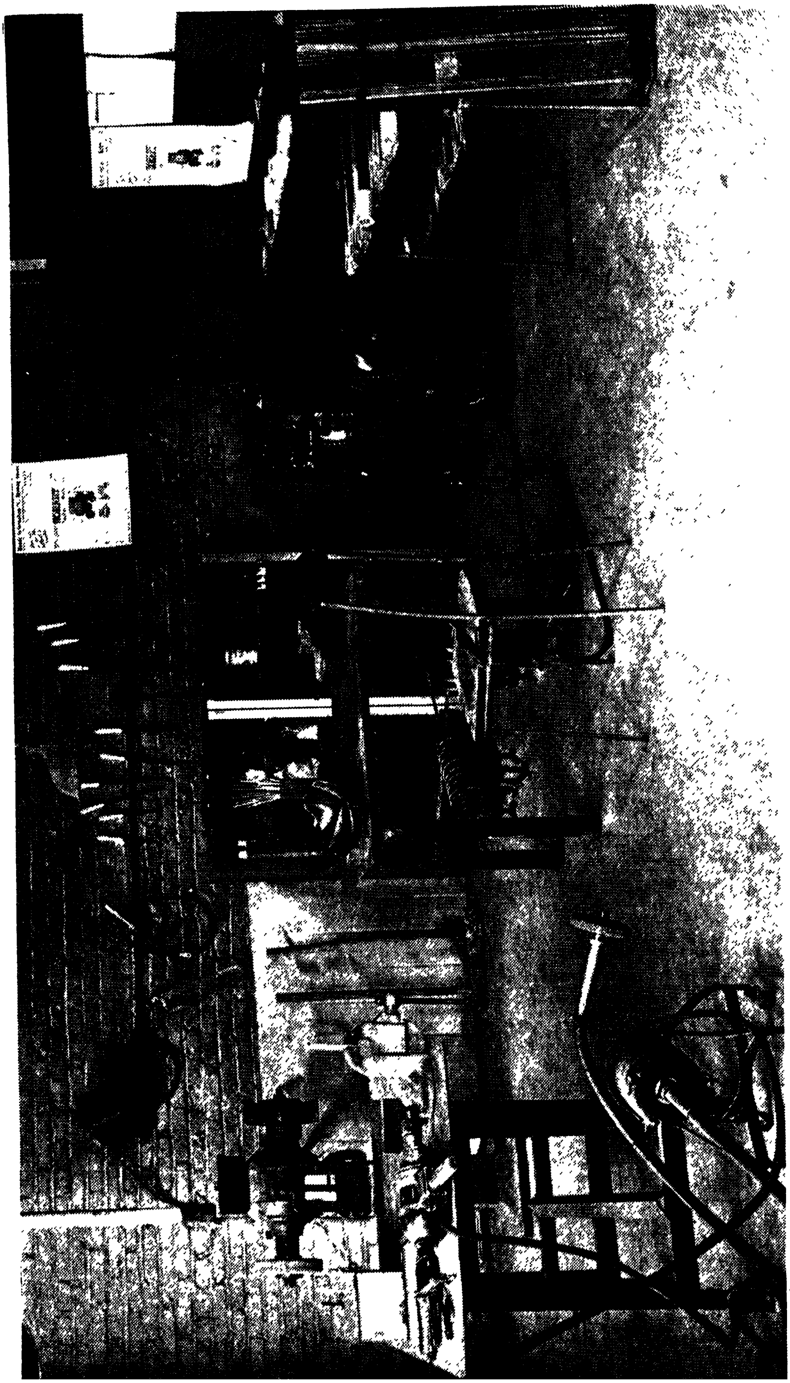


Figure 216. An arc welding shop. Note the storage bins and the grinders
(Courtesy of: Hobart Bros. Company)

ones in use at the present time are the spot welder and the butt welder. As these two machines lend themselves very nicely to production work, this use enables the welding shop to bid on, and do small production work for outside concerns. They can also be used

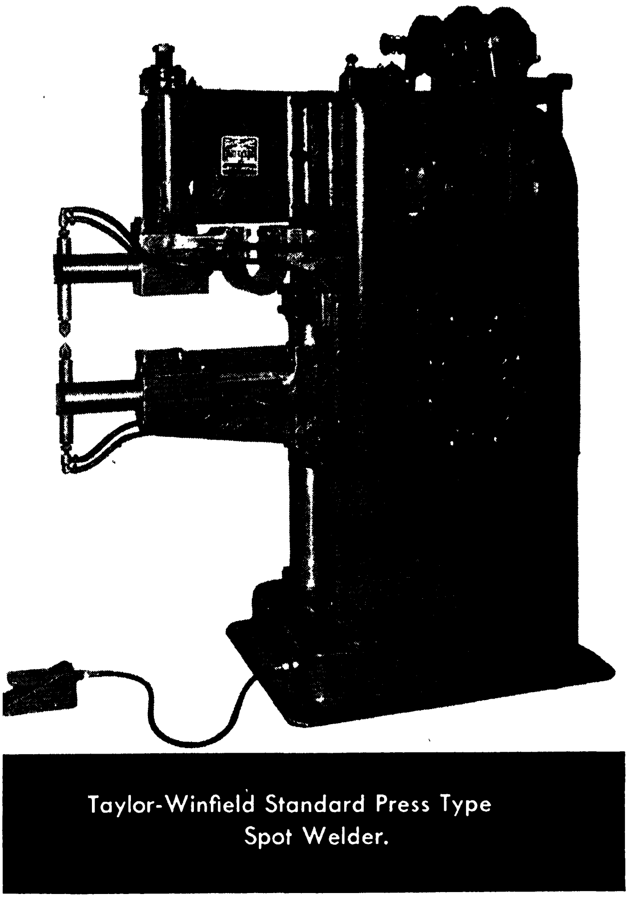


Figure 217. A spot welder for heavy production work
(Courtesy of: P. R. Mallory and Co., Inc.)

for pre-fabricating structures prior to oxy-acetylene, or arc-welding them. Usually these machines are few, inasmuch as the equipment itself contains the necessary features for holding the work while it is being welded. The accessories needed are: gloves, clear glass goggles, and pliers or tongs. *Figure 217.*

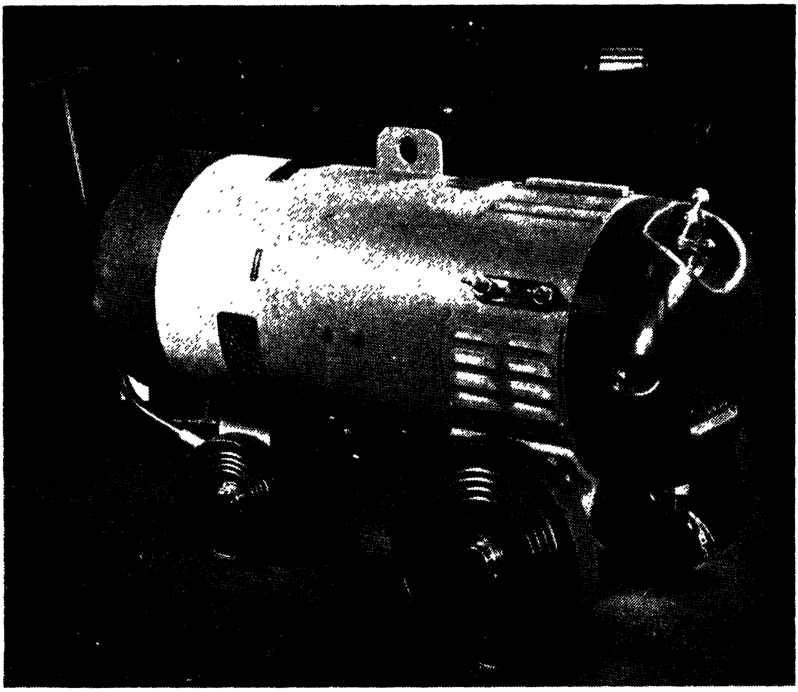


Figure 218. A portable D.C. arc welder
(Courtesy of: Westinghouse Electric and Mfg. Company)

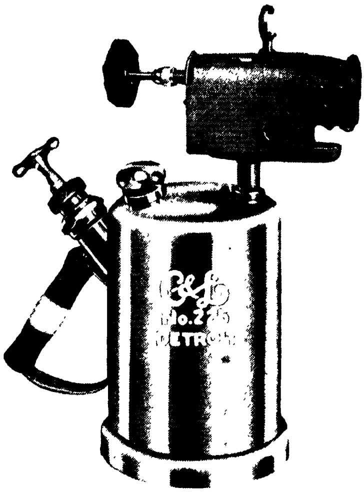


Figure 219. A blow torch that may be used for preheating
(Courtesy of: Clayton and Lambert Mfg. Company)

273. Preheating Furnaces

A preheating furnace is a necessity for practically all welding shops. As previously explained, complicated metal structures, when

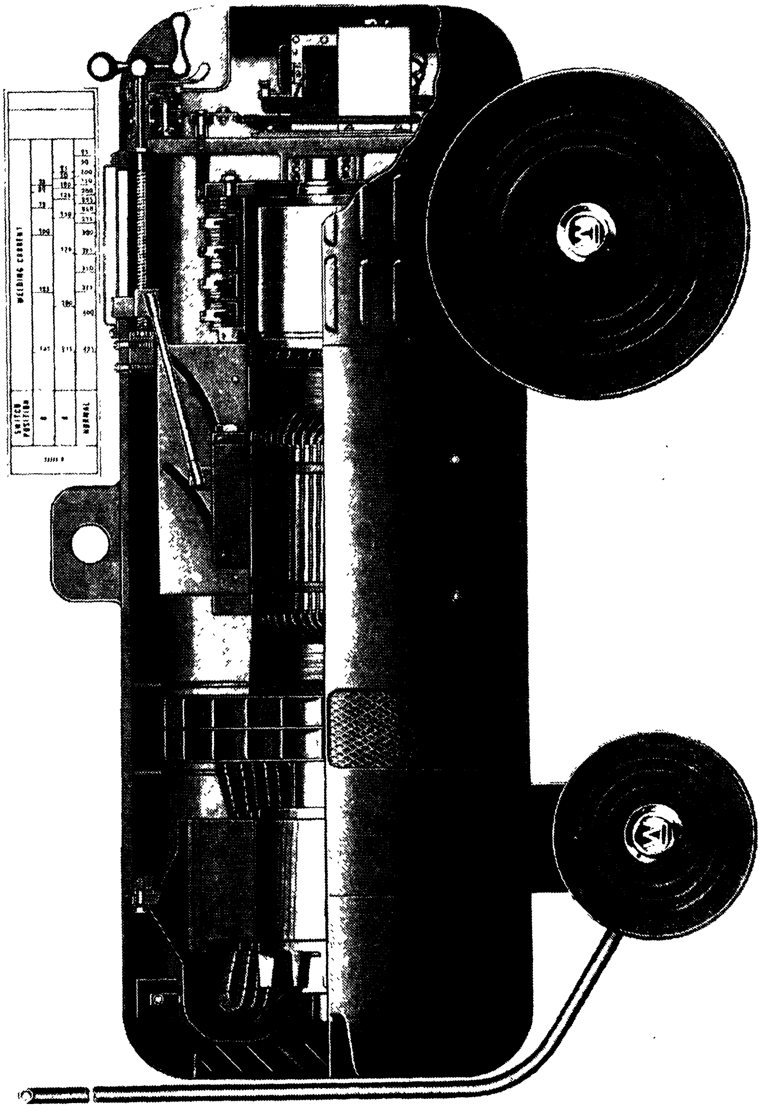


Figure 220. A cross section of a D.C. arc welder
(Courtesy of: Westinghouse Electric and Mfg. Company)

welded, are subject to excessive straining and perhaps, breakage if they are heated or cooled unevenly. To eliminate this, the whole structure is heated gradually to the correct temperature before the necessary welding is performed. The structure is then allowed to cool slowly and evenly after the welding is completed. This makes

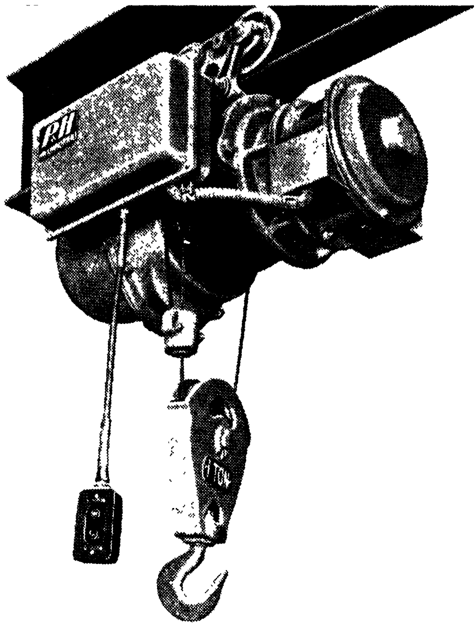


Figure 221. An electrically operated overhead crane or hoist
(Courtesy of: Harnischfeger Corporation)

possible a minimum of warpage; it also prevents excessive stresses and cracking of the metal as it cools to room temperature. The preheaters come in three styles: the portable torch type, the flat top open type, and the enclosed furnace. The torch type is a large portable blow torch. *Figure 219.* These may use city gas, oil, gasoline, or kerosene as the fuel; they may use air or oxygen as the combustion supporting gas. These furnaces, or heaters, are used for the smaller metal structures or for locallized preheating.

The open flat-top preheater is the most popular type and consists of a grate, or series of bars, underneath which are the gas burners. The article to be preheated is placed on top of these bars or grates.

Clay and fire bricks are usually built up around the article to be preheated in order to enclose it. This shield may also protect the welder from the heat from the furnace which is dissipated into the

room, making working conditions uncomfortable, especially in warm weather.

The big advantage of this type of furnace is its flexibility in that the article being preheated, or welded, is readily accessible if certain bricks or asbestos sheets are removed. The article may be welded while it is still located on the furnace.

The enclosed type of preheating furnace is a typical furnace which may be used for heat treating, carburizing, or preheating. It consists of a fire-brick-lined, steel structure and usually uses gas for fuel. A forced air blower is usually used for supporting the com-

Figure 222. A blacksmith's forge
(Courtesy of: Buffalo Forge Company)

bustion and for raising the temperature. The big advantage of this furnace is its economy, its ability to cool the article very slowly for annealing purposes, and the dissipation of the heat out of doors rather than into the shop. It has the one disadvantage of usually requiring that the article to be welded must be removed from the furnace after preheating in order that it may be welded, which in some cases prevents the use of this type of furnace.

274. Overhead Crane

The size of the work to be handled by the welding shop may necessitate the use of power equipment for moving the article to be welded from place to place.

In the small shop, a chain fall, either hand driven or motor driven, may be suspended from rails or beams, which run the length of the shop; or a portable crane which runs on tracks along the sides of the shop. Of the three, the overhead crane is the most applicable. It enables an article to be moved from any part of the shop to any

other part without interfering with any operations proceeding on the floor. *Figure 221.*

275. Forge

Many times a welding shop is called upon to heat-treat articles after they have been welded, or as a special job for outside concerns. The forge has some advantages over a welding torch for this purpose, and the use of this article more than provides the proper return on its investment. The forge is a typical blacksmith forge,

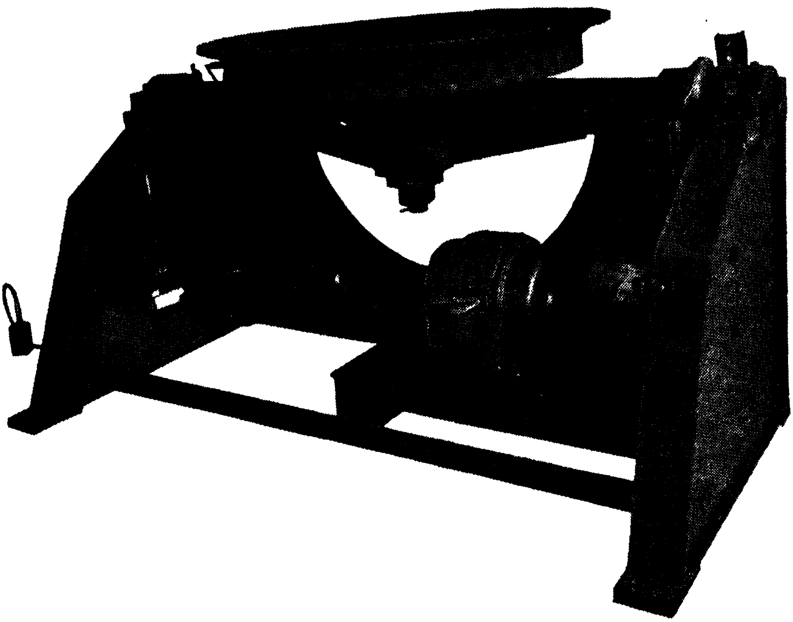


Figure 223. A welding turntable
(Courtesy of: Harnischfeger Corporation)

using forced air which comes into the forge fire from underneath and which has a vent to the outdoors through a hood located over the forge fire. *Figure 222.*

276. Jigs and Fixtures

One of the greatest problems, encountered in a welding shop, is to prevent the metal from warping out of line during the welding operation, or during the cooling after the welding operation. Many devices have been used to hold the metal during the welding so that the warpage and bending of the metal will be reduced to a minimum.

Clamps, vee-blocks, vises, and special holding jigs are used extensively for this purpose. Also, where any quantity of articles of the same type are to be made, it is necessary to design and make jigs to hold these articles to insure that the finished products will be identical. Angle iron and large cast iron, or steel grooved face plates may be used to advantage for fixtures of this kind. *Figure 223.* Turn tables, horizontal, vertical, or tilting, are also popular in shops especially in production work.

The turn table consists of a fixture and a face plate, mounted on roller, or ball bearings, to which any work may be fastened. The operator then has only to stand in one position while welding and the work is turned to face the operator as the welding proceeds. This enables welds of all kinds to be turned until they become flat welds; these fixtures also minimize the physical exertion on the part of the welder. This type of jig may be purchased from equipment companies.

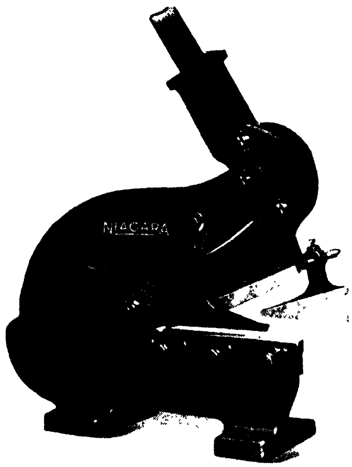


Figure 224. A hand shears for cutting steel stock
(Courtesy of: Wedlit Acetylene Company)

277. Power Drills and Grinders

A drill press, or a portable electric drill, is necessary in a welding shop to drill holes for reinforcing cast metal welds and to help prepare pigs and fixtures. *Figure 225.* Power grinders of the pedestal type and also the flexible shaft type are invaluable for preparing metals for welding and for grinding the finished welds. Grinders are also useful for identifying various kinds of steel. *Figure 226. 227 and 228.*

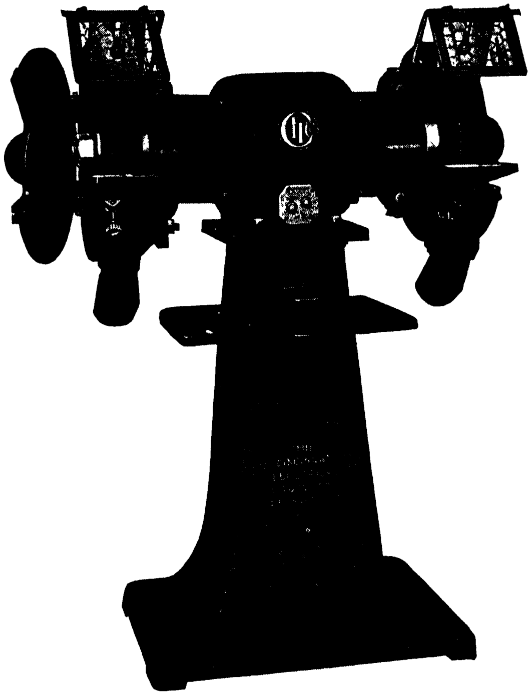


Figure 225. Power grinder
(Courtesy of: The Cincinnati Electric Tool Co.)

Figure 226. A portable electric grinder
(Courtesy of: The Cincinnati Electric Tool Co.)

Figure 227. A portable grinder being used to grind the welds of a pipe elbow prior to painting
(Courtesy of: Norton Company)

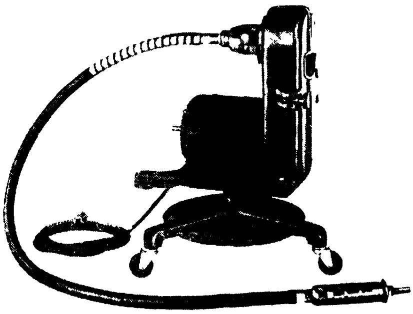


Figure 228. A flexible shaft grinder
(Courtesy of: Walker Turner Co., Inc.)

278. The Welding Job Shop

As mentioned in the introductory paragraph of this chapter, there are two different types of shops which specialize in the fabrication of structures by welding, or repairing structures by welding. These two types do very similar work and, therefore, may be treated as one in the remainder of this chapter. These shops will be called "welding job shops" in this text, a name which is descriptive of the fact that these shops specialize in welding jobs. This type of shop

will need all the necessary equipment explained in the previous paragraphs and, in addition to these, it will need a certain number of tools and supplies.

279. Welding Shop Tools

The kind and number of tools the welding shop needs depends entirely upon the kind of work the shop desires to do. The shop may prepare the metal for welding and weld it, or it may specialize in the welding operation itself. In the former case, a complete metal working department is a necessary part of the set-up; the most necessary metal working tools for the department are a sheet metal brake and power shears. As these two items are rather expensive, the smaller and medium-sized welding shops cannot afford to install them. The typical method of procedure is to have a centrally-located metal fabricating company which will prepare the metal after which it is sent to the welding shop to be assembled.

A very necessary part of the welding shop is the cutting equipment. Every welding shop, regardless of its size, must have one or more of the automatic cutting machines to enable accurate shaping of the metal prior to welding.

The accessory tools, needed in a welding shop, are:

1. Wrenches
   - (a) Welding equipment wrenches.
   - (b) End wrenches for dismantling and assembling various articles.
   - (c) Cylinder wrenches especially for the acetylene cylinder.
   - (d) Pipe wrenches for preparing pipe material for welding.
2. Hammers of several sizes such as one, two, and four pound ball peen hammers for general work, and sledge hammers for straightening and bending heavy stock.
3. Chisels.
4. Files of all types and sizes.
5. Screw drivers.
6. Wire brushes.
7. Power grinder dresser.
8. Grinder goggles.
9. Squares, levels, clamps, mallets, and soldering coppers.

280. Welding Shop Supplies

As the supplies of a welding shop are rather numerous, it is

recommended that the reader refer to Chapters 2 and 4 for complete descriptions of various supplies. A list of more popular supplies is as follows:

Gases

(a) Oxygen
(b) Acetylene
(c) Occasionally some preheating gas (City Gas, propane, etc.)

Filler rod (Oxy-Acetylene Welding)

Steel

1/16", 3/32", 1/8", 3/16", & 1/4", dia.

Cast Iron

1/8" & 1/4" round

Aluminum

1/8" round drawn, and 1/4" square casted rod

Miscellaneous filler rods for special welding tasks

Electrodes

The electrodes may be the bare, unprotected type, or one of the several types of coated electrodes. The commercial welding shop usually prefers the coated style.

Steel

1/8", 3/16", & 1/4" round

Nickel, steel, copper, aluminum, stainless steel, electrodes will also be needed for special welding tasks.

All of the above are electrodes used for application as their name implies; the welding shop should follow the detailed instructions of the electrode manufacturer in order to secure the best results.

Metals

A welding shop should have on hand at all times a quantity of the various standard sizes of sheet steel, which supplied in standard plate sizes, and may be stored in the warehouse of the shop until used. *Figure 229.* The various alloy metals and variations in the carbon content of the iron-carbon steels should be identified by carefully marking on the metals. It is preferable to paint each piece a different color and to keep a code on hand indicating the steel analysis for the various colors. The above is becoming exceptionally important since the very rapid growth of a multitude of special steel alloys which, if they were confused with one another, would tend to destroy the chance of obtaining good welds. A quantity of pipe stock should be kept on hand for standard fabricating use. Angle iron of various sizes is also an important item. Flat stock and round solid rod are not frequently used in a welding shop, but a

U. S. Standard Gauge for Steel Sheet

Gauge No.	Decimals	Fraction	Weight Per Sq. Ft. (Lbs.)
0000000	.5	1/2	20
000000	.469	15/32	18.75
00000	.438	7/16	17.5
0000	.406	13/32	16.25
000	.375	3/8	15.0
00	.344	11/32	13.75
0	.313	5/16	12.5
1	.281	9/32	11.25
2	.266	17/64	10.625
3	.25	1/4	10.0
4	.234	15/64	9.375
5	.219	7/32	8.75
6	.203	13/64	8.125
7	.188	3/16	7.5
8	.172	11/64	6.875
9	.156	5/32	6.25
10	.141	9/64	5.625
11	.125	1/8	5.
12	.109	7/64	4.375
13	.094	3/32	3.75
14	.078	5/64	3.125
15	.070	9/128	2.812
16	.0625	1/16	2.5
18	.05	1/20	2.0
20	.0375	3/80	1.5
22	.0312	1/32	1.2
24	.025	1/40	1.0
26	.0187	3/160	.75
28	.0156	1/64	.625

Figure 229. A table of sheet steel specifications

quantity should be kept on hand for special jobs. This will increase the overhead of the shop, but this is more than compensated for by the time saved when this material is needed on certain occasions.

Fluxes

Fluxes are used principally when oxy-acetylene welding is done. The common fluxes kept on hand are:

Brazing Flux.

Cast Iron Welding Flux.

Aluminum Flux.

Cast Iron Brazing Flux

It is very important that these fluxes be kept in sealed containers and in a cool, dry place when not in use. It is further recommended that when using the flux, only enough should be transferred to a smaller container to perform the particular task. This action will keep the larger supply clean and fresh.

Carbon Backing Material and Carbon Electrodes

Carbon is excellent material for backing welds and for forming small forms or molds, particularly for places that are hard to reach. The carbon helps to shape or form the metal as it is being puddled by the torch or electrode arc. This may be either flat stock, square stock, or round stock; the paste is sold in sealed containers and may be formed to any shape, but upon contact with the air the paste slowly solidifies.

Carbon electrodes are used for carbon arc-welding and may be obtained in different diameters. They are made of carbon or graphite, but the graphite electrodes are considered the better of the two.

Vitrified Fire Brick

This material is used for bench tops and for enclosing articles that are to be preheated. They are also used to slow up the cooling rate of an article.

Miscellaneous

Glycerine for lubricating oxy-acetylene moving parts and wiping cloths for cleaning purposes.

The amount of the supplies listed above depends entirely upon the amount of work the shop performs and the type of work in which it specializes. The only recommendation that can be made at the moment is to be conservative in purchasing the above supplies until experience dictates the proper amount to carry on hand.

281. Welding Shop Policy

It is difficult to list in this text the policies that a welding shop should pursue in order to maintain correct business relationships. The work should all be done under a legal contract basis with clearly and definitely defined provisions for all emergencies. The welding shop should be extremely careful as to the metals being worked on; if the metal is being supplied by a person desirous of having the article manufactured, this item should be very carefully investigated in order that the use of any poor stock will not be detrimental to the welding shop. The welding shop should list the specifications of the metal when purchasing and should hold the supplier of the material to these limits. This last item is not difficult because the large steel companies furnish metallurgical and chemical specifica-

tions of their steel, and guarantee them to be within certain close limits. Frequently the welding shop must estimate the final cost of fabricating an article to some concern prior to starting work. This takes considerable training and experience. To estimate it properly, two items must be considered as main determinants:

(1) The length and depth of the welds.
(2) The type of weld that is straight-in line, flat weld, curved weld, vertical weld, or overhead weld.

Such other variable items as type of metal being welded, the type of filler rod, fluxes, electrodes, etc. being used, also affect the final cost of the jobs. These latter factors are constant, however, and by a matter of simple calculations the estimator may estimate these items quickly. For example, accurate information may be obtained from welding supply houses as follows: how long, how much filler rod, or electrodes, and how much gas or electricity may be involved in making welds of certain lengths and in various thicknesses of metal.

With this basic information, the estimator can quickly determine the labor cost, the cost of material, and the power cost. Another item that should not be neglected in estimating the cost is the matter of handling the material to be welded. When dealing with small articles, this may be neglected; but with large cumbersome forms which have to be moved from one part of the shop to another and turned in various positions, this item is extremely important; by neglecting this it may increase the cost of the welds as high as 20% to 25%.

Included in the contract, an item should be inserted carefully wording the matter of moving costs. Either party may take this responsibility; this involves moving the articles to the shop to be welded and returning the completed article to the person contracting for the work.

Certain cases where the completed article weighs a matter of tons, this item becomes of outstanding importance. As with many other kinds of work, estimators, after gaining considerable experience, can estimate by eye and by mental calculations the approximate cost of a weld job. However, this method is not infallible and should always be backed by a complete, detailed calculation. A welding shop should be extremely careful in regard to the guarantees it issues in reference to certain welding jobs. Guarantees concerning the amount of time to be taken for preparing a certain unit should have a clause concerning the quality of the finished job. Experience and the difficulty of the job limit these guaran-

tees; however, the contract should also have limiting clauses, especially in regard to the effect of poor metal on the cost of the finished product. A lawyer who specializes in drawing up industrial contracts should be employed to draw up a standard form that may be applied to all types of welding jobs undertaken in the shop.

282. The Welding Equipment Repair Shop

Practically all manufacturers of welding equipment maintain shops whose sale purpose is to overhaul used welding equipment and repair it for the various welding jobbers. Some large manufacturers, who do an extensive amount of welding, have included a welding-equipment, repair shop as a part of their large welding plant. Welding-equipment repair may be divided into three divisions.

1. Oxy-acetylene equipment repair.
2. Arc welding equipment repair.
3. Resistance welding equipment repair.

283. Welding Equipment Repair Tools, Parts, and Supplies

The oxy-acetylene and equipment repair need various equipment.

Lathe.

Drill Press.

Soldering apparatus.

Welding Station for Testing.

Repairing equipment (jigs and fixtures).

Bench and vises.

Storage bins for parts.

Grinder and buffer.

The tools needed in a repair shop of this kind are:

Lathe accessories which should consist of universal chuck, drill chuck, tool bit holders and centers.

The small hand tools necessary in a shop of this kind are shown in *Figure 230.*

A set of open-end wrenches.

A set of numbered and lettered drills.

Large open-end wrenches and box wrenches.

Assembling and dismantling jigs.

Calipers, both inside and out.

Micrometers.

A set of center punches.

A set of socket wrenches and handles ranging from 7/16″ to 1 3/8″.

A small ball peen hammer.

A leather mallet.
A small torch or soldering copper.
A set of dies and a die stock.
A set of taps with a tap wrench.

It will be found necessary to use various special jigs and fixtures for holding the different parts of the apparatus while it is being

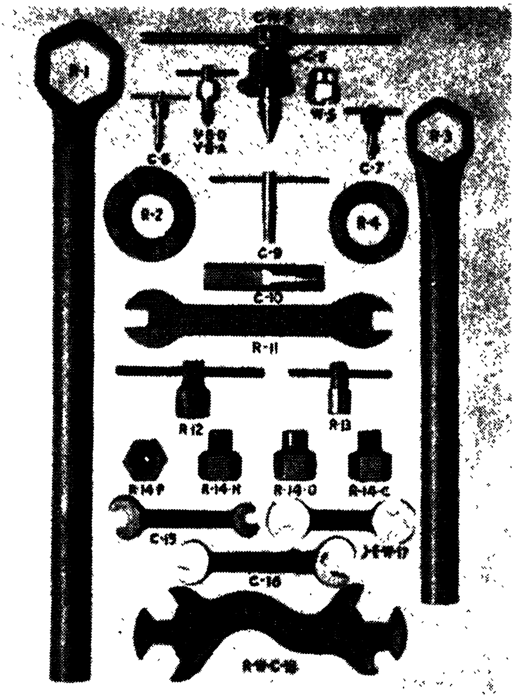


Figure 230. Special tools for repairing gas welding equipment
(Courtesy of: Victor Equipment Company)

repaired. The most common of these are different jigs for holding the body of the regulator while the bonnet is being fastened to it, and fixtures for holding the various parts while they are being fastened together. *Figure 231.*

Necessary parts of the repair shop are the various devices for testing an apparatus after it has been repaired. Acetylene regulators and gauges are tested on acetylene cylinders, with master gauges also connected to determine the operation; while oxygen regulators and gauges are tested on oxygen cylinders to determine their operation. Never test acetylene parts with oxygen, or oxygen parts with acetylene.

The supplies needed in a welding repair shop are:

Sand paper.

Emery paper.

Solder; silver, lead, and tin solder (50-50).

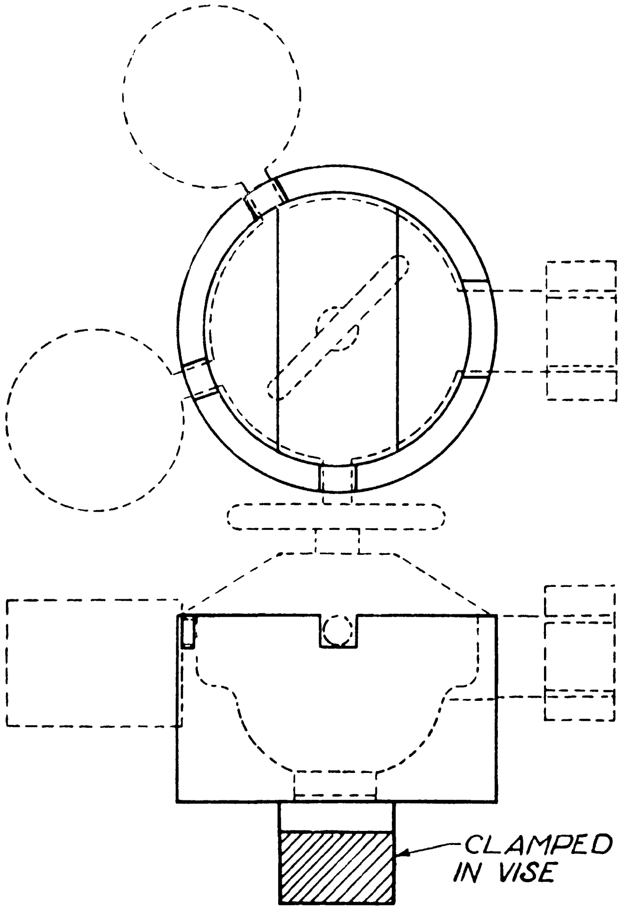


Figure 231. A jig for holding regulator in a vise while repairing them

Glycerine.

Litharge.

Cleaning cloth for polishing abrasives.

The equipment replacement parts necessary to maintain a welding repair shop are:

Nozzles and seats for the nozzle type regulators.

Diaphragms for all type regulators.

Gaskets for all type regulators.

Needles and seats for stem type regulators.

Torch valves for all type torches.

Hose, both oxygen and acetylene.

Hose nipples and nuts for both oxygen and acetylene.

Torch valve packing for both the oxygen and acetylene torch valves.

Hose clamps for both the oxygen and acetylene hose.

Several main parts of different types of torches, such as handles, mixing chamber, barrels, and tips.

Several main parts of regulators, such as bonnets, regulator adjusting screw springs, seat retaining cage, etc.

Adaptor fittings for connecting the hose to the regulators.

Gauge parts such as needles, dials, crystals, bezels, etc.

284. Repairing Oxy-Acetylene Torches

As explained previously, a torch (blow pipe) consists of shut-off valves, handle, mixing chambers, barrel, and tip. Three different fundamental torch designs have been used. They are based on the location of the mixing chamber.

1. A chamber formed between the tip and the tip socket is used as the mixing chamber. This allows for a different sized mixing chamber for each size of tip.
2. The mixing chamber is located inside the handle of the torch and is usually placed between the handle and the barrel junction.
3. The barrel and tip are made in one piece with the mixing chamber located between the barrel and the handle, thus enabling the mixing chamber size to be changed for each sized tip.

The latter type incorporates features of the first two because it is ideal to change the size of the mixing chamber with each tip size; it is also a good practice to keep the mixing chamber remote from the source of heat in order that pre-ignition may not take place. However, the disadvantage of this latter type is the increased cost of each tip.

285. Repairing the Torch Valves

The troubles usually encountered with torch valves are leaks past the needle, or leaks around the valve packing nuts. The typical torch valve is of needle design, using a drop forged brass body, drilled and threaded, and a brass threaded needle with either a Vee tip or a ball-bearing tip. The body of the valve is threaded to receive the threads of the needle. *Figure 232.* Being made of brass,

these threads strip quite easily in case of abuse; the only repair in this case is to replace the complete valve. To replace a valve in a torch it is necessary to un-solder (usually silver solder) and un-thread the valve from the torch and replace it with a new one. One must place the valve on the torch in a convenient position before re-soldering it to keep the operator's hand from interfering with the adjustment. It is also quite often necessary to repack around the valve needle to prevent leaks at this point. Leaks around the

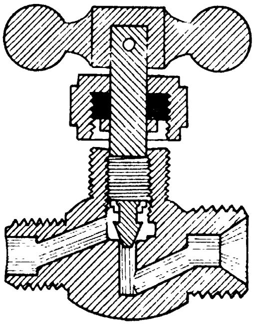


Figure 232. A torch needle valve
(Courtesy of: Weldit Acetylene Company)

valve needle are dangerous because they mean a continuous loss of gas. When repacking a valve needle, it is recommended that the old packing be completely removed and that only new material (asbestos rope) be used. It is important to use a correctly sized wrench on valve packing nuts to prevent their stripping and to prevent the rounding of the hexagonal corners.

The only difficulty sometimes encountered with torch handles is that the handle, being made of a thin brass tube, sometimes becomes loose and turns freely on the torch. This makes the torch difficult to hold. To remedy this the handle may be silver soldered to the stationary parts of the torch, or may be tightened if the torch is provided with retaining sirens.

286. Repairing the Mixing Chamber

It is difficult to recommend repairs for the mixing chamber because of the importance of not abusing the surfaces of this very important part of the torch. The mixing chambers are very accurately designed and are very carefully machined to promote the proper mixing of the two gases. If the parts forming the mixing chambers are very carelessly handled, the welding ability of the torch may be completely ruined. If the parts are abused, that is,

scratched or bent out of shape, the only recommendation is a replacement of these parts. *Figure 233.* The most common difficulty encountered with mixing chambers is the carbon formation which sometimes takes place and which coats the walls, thus changing the size of the chambers and preventing good mixing of the two gases. It is necessary that the carbon be removed and the surfaces given their original bright finish. To do this, carbon dissolving agents should be used in conjunction with a soft cloth. Never use sandpaper or emery cloth to clean mixing-chamber surfaces.

Polishing paper such as 000 or 0000, French Hubert paper is permissible, but should be used very carefully. When repairing parts of a mixing chamber, it is very important that only genuine parts be used, if possible. If the shop is to make parts for replacement, it cannot be emphasized too strongly that the tolerance during machining should be kept less than one thousandth of an inch. Also if a repair shop is to make its own parts, it is emphasized that careful consideration be given the material from which the part is being made. If the material is some usual alloy, a rapid deterioration may take place in the presence of acetylene or oxygen. Sometimes the chemical reaction between the gases and certain metals becomes dangerous. A welding shop, doing any considerable amount of manufacturing of its own parts, should secure an alloy which is inert to the action of these two gases.

287. Repairing the Torch Barrel

The design of the torch barrel depends on the type of torch. One type of torch does the mixing of the two gases in the handle and another type mixes the gases in the head. In the newer types of torches where the mixing takes place in the handle, the barrel is usually made of drop forged, or extruded brass, rifle bored, and bent to shape according to the purchasers' specifications. Three parts of this barrel are common sources of trouble. First, where the barrel is attached to the handle, a clamp nut is used to provide a leak-proof joint. If abused, the torch will leak at this point and relapping, remachining, or replacment is necessary to stop leaks.

The barrel itself sometimes crystallizes and breaks because of excessive twisting or pounding. These barrels have sometimes been repaired by brass welding, or silver soldering. However, this is only a makeshift repair; replacement of the complete barrel is a recommended policy.

The socket whereby the tip is fastened to the barrel is another source of trouble. This is due first to the stripping of the threads

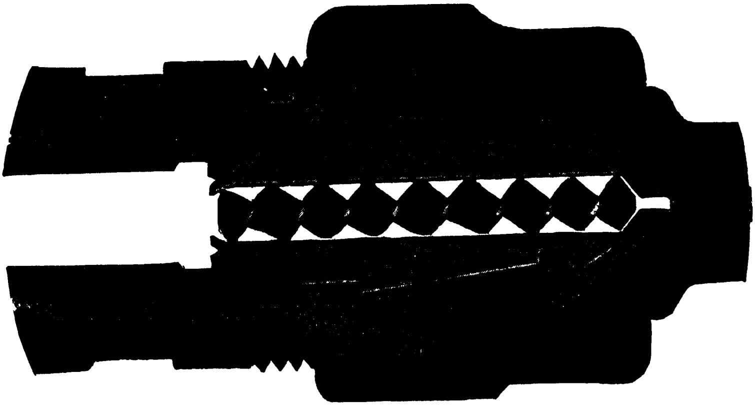


Figure 233. A torch mixing chamber showing the oxygen as yellow and acetylene as red. The flow is from left to right. The spiral oxygen flow produces a whirling, turbulent gas that is said to provide better mixing of the acetylene and the oxygen in the mixing chamber (extreme right)
(Courtesy of: Victor Equipment Company)

and second, to the abuse of the sealing surfaces, which may permit the gas to leak out around the threads. Here if they burn, they will preheat the tip, causing the torch to backfire. If the threads of the head are stripped, replacement of the complete barrel is necessary; while if the seat used as a sealing surface is abused, an end reamer may sometimes repair the trouble; but if this is not successful, replacement will be necessary. Occasionally small leaks, which occur at the point where the tip threads into the barrel, may be stopped by applying some bar soap to the threads. The soap will act as a sealing compound when the two are threaded together. It should be emphasized here that most of the abuses to which a torch is subjected are the result of the operator's forgetting that brass and copper parts are soft. It should also be emphasized that brass parts, when threaded together, need not be tightened as tight as steel in order to secure a leak-proof joint. That type of torch which uses a separate barrel and tip for each size of welding tip has practically the same trouble as the torch with the mixing chamber in the handle. This contribution, however, eliminates a joint between the tip and the handle. Holders, made of wood or soft metal such as lead, should be used for holding these parts while they are being worked on.

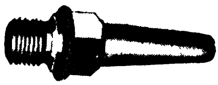


Figure 234. A torch tip
(Courtesy of: Modern Engineering Company)

288. Repairing Torch Tips

The part of the torch which is subjected to the most severe abuse is the torch tip. The tip is immediately adjacent to a high temperature flame and in many cases much of the heat is thrown back directly against the tip. To withstand this service, the tip is usually made of hardened copper. Steel cannot be used to advantage for this purpose because it cannot remove the heat rapidly enough, and soon becomes hot enough to pre-ignite the gases.

Even though hard copper is used for the tip, this material is still soft enough to be easily injured. The three parts of the tip which most frequently give trouble are the orifice, the threads, and the seat.

The orifice, the opening through which the gas is fed to the flame, must be carefully treated. This orifice is usually drilled to size and is accurate to the thousandth of an inch. The exact size will vary

with each manufacturer. *Figure 234* shows a table listing the different size drills for the different tip sizes used by one particular manufacturer. This table is not to be taken as the exact drill sizes for all sized tips.

As the tip is being used, metal particles adhere to the outside of the tip; some may find their way to the interior of the orifice where they will interfere with the gas flow. These foreign particles must be removed. A special reamer, made of tool steel, is obtainable for removing these particles. Because of their small size and their hardness, these reamers sometimes break while being used. This makes it imperative that they be used carefully. These reamers may also enlarge or score the orifice walls to such an extent that the tip becomes worthless. The tip should be removed and cleaned by inserting the reamer from the inside.

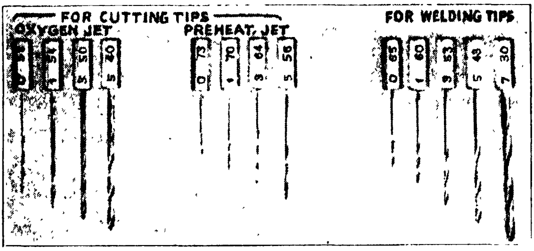


Figure 235. Torch tip drills and sizes
(Courtesy of: Victor Equipment Company)

Many welders use a soft steel or copper wire of the proper size to remove the foreign particles from these orifices. Some welders prefer to refinish an ice pick into an extremely long, needle-like point and use it for this purpose. *Figure 235.*

While reaming a tip, it is always best to ream it from the inside toward the outside where the flame takes place. However, the convenience of reaming the tip from the outside is often the reason for attempting to clean a tip in this manner. If an operator does ream the tip from the outside (while the tip is fastened into the barrel), the oxygen should be turned on while the reaming is in process. This will help to blow the particles out of the torch as soon as they are loosened. The same repairs, recommended for the seat and threads of a barrel are also applicable to the threads and seat of the torch tips. The shape of the tip at the end where the gases burn is very important when one is attempting to secure a proper flame. Because of the constant high temperature the edges

of the orifice tip wear away, thus widening or enlarging the orifice. *Figure 236.* This bellmouth prevents accurate and complete combustion, and enables the torch to blow out too easily. To remedy this the repair man may remachine the tip in a lathe, or he may file the tip until the bellmouth is removed. This operation is especially important in the maintenance of cutting torch tips.

289. Repairing Regulators

As mentioned in Chapter 2 there are various types of regulators. However, the two fundamental designs in reference to repair work are the stem type and the nozzle type. Practically all regulators, regardless of the trade name, are repaired by following the same general procedure. The two most common regulator repairs are to the valve proper, which should not leak, and to the diaphragm, which should not be buckled or injured in any way.

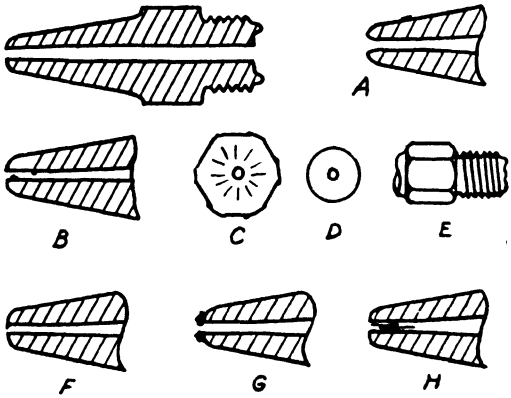


Figure 236. Torch tip cross section showing undesirable bell mouth, etc.: A. Bell mouth, B. Dust particles inside orifice, C. rounded hexagon, D. Bruised orifice, E. Battered seal face, F. End of orifice pounded over, G. Dust particle partly clogging tip, H. Scratches on orifice wall

290. Repairing the Nozzle Type Regulator

This type of regulator embodies the use of a diaphragm which controls the movement of the seat against a hard copper nozzle. This construction is usually called the reverse valve and seat construction. The seat carriage is either fastened to the diaphragm, or when the diaphragm is released, a spring forces the seat tightly against the nozzle. *Figure 237.* It is extremely important that the diaphragm be able to move freely in all positions to eliminate any jumps or catches caused by the warping of the diaphragm. A buckled diaphragm can be detected by inspection. Old diaphragms

have a tendency to dish, or have a snap action, meaning that as the diaphragm moves in one direction, it will snap a definite amount after passing the neutral point, preventing accurate adjustment of the regulator over any pressure range. This is usually the result of worn diaphragms that have been in use long enough to cause a working of the diaphragm metal, producing the dishing or snapping action.

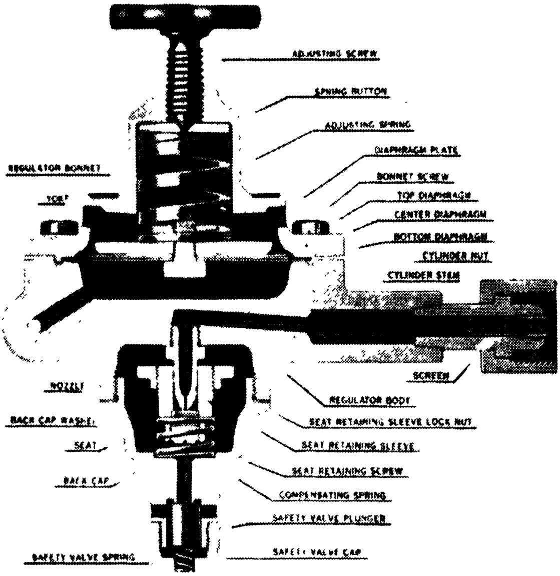


Figure 237. A nozzle type regulator
(Courtesy of: Torchweld Equipment Company)

A buckled diaphragm, having a surface wrinkle, is usually the result of unskilled installation. A dished diaphragm, or a warped diaphragm, may force the seat carriage from its true line and cause serious troubles by making the seat carriage bind its guides. It may also produce a leak at the nozzle and seat. It is very important upon the assembly of these regulators that all the parts work freely in order to secure the desired accuracy of seating. The seat is retained within the seat carriage by means of a small threaded retaining washer.

These washers may be turned by means of a large screwdriver, or preferably by means of a special two-pronged wrench.

After a certain period of use, the seat should be either replaced or reversed to provide a perfectly smooth surface to contact the

nozzle. It is very important that the part of the carriage holding the seat should be perfectly clean before the seat is installed, as a small dirt particle will put it out of alignment.

The nozzle, being made of hard copper and very finely machined with an accurately drilled opening or orifice, does not often require repair. *Figure 238.* However, under excessive abuse there is a tendency for the end of the nozzle to become scored. The only recommended procedure is to replace the nozzle, inasmuch as filing or sandpapering will not produce a true surface. The nozzle may be mounted in a lathe and remachined. However, this shortens the length of the nozzle and places a heavier burden on the springs and diaphragm for correct operation; nor will the regulator give the service expected.

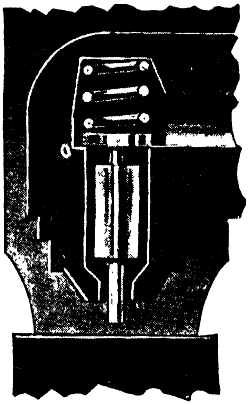


Figure 238. The details of the nozzle and seat
(Courtesy of: Modern Engineering Company)

The inlet or the high pressure gases has been standardized as to thread-size design. These standards are explained in Chapter 2. These fittings are different for different gases, but all oxygen cylinders, for example, use the same type of fitting. However, it is standard practice to fasten any and all of these fittings to the regulator body by means of a 1/4″ Briggs Standard pipe thread silver soldered.

The gauges are also fastened into the regulator by means of 1/4″ pipe fittings and the joint is sealed by the use of litharge and glycerine. The inlet opening to these regulators is usually provided with a fine mesh screen (approximately 100 mesh). This should always be cleaned as a part of the regulator repair operation. It is recommended that during the overhauling of the regulators the various parts be buffed with a cloth buffing wheel, to remove any surface

dirt clinging to them. Also the parts may be acid dipped either in a cold solution of cold nitric acid, or in a warm solution of sulphuric acid. Great care must be exercised to prevent injury to the person doing the acid cleaning. The regulator adjusting screw usually threads into the bonnet and frequently requires repair because of sticking of stripped threads. To lubricate these threads, glycerine or soap may be used. (OIL MUST NEVER BE USED ON OXY-ACETYLENE EQUIPMENT.) Diaphragms are fastened to the body of the regulator by means of soldering, or they are clamped between the body and the bonnet. The bonnet is either threaded to the body regulator, or is fastened by a number of small cap screws or machine screws. The latter construction is much more easily repaired. However, the assembly in either case must be exceptionally well done or buckling of the diaphragm results, spoiling the correct operation.

When assembling the nozzle and seat type regulator it is extremely important that the regulator adjusting screw be turned all the way in during the assembly. This applies particularly to the installation of the valve seat. If this is not done, the soft valve seat, sliding across the nozzle opening, will become permanently injured and prevent it from working correctly. See Paragraph 292 for instructions on how to test a regulator.

291. Repairing the Stem Type Pressure Regulator

The care required in handling the fittings, the adjusting screws, the diaphragms, the body, and the bonnet apply to the stem type of regulator as well as to the nozzle type. The construction of the valve proper, however, is different. The stem type of regulator, as explained in Chapter 2, uses a soft valve seat, usually rubber, against which a poppet valve is pressed by means of a spring and the gas pressure. The poppet valve stem passes through the valve seat opening, and the end of it is manipulated by the regulator diaphragm. This stem is very seldom fastened to the diaphragm. *Figure 239*. It is forced against the seat by means of a spring which presses against the head of the valve. Also the inherent flow of the high gas pressure tends to force the valve against its seat. The valve and head are usually assembled in a housing or cage to assure their proper alignment. It also minimizes the amount of labor in assembling and insures that the valve and seat are gas tight.

292. Testing a Regulator

To test a regulator after assembling, one should use oxygen for

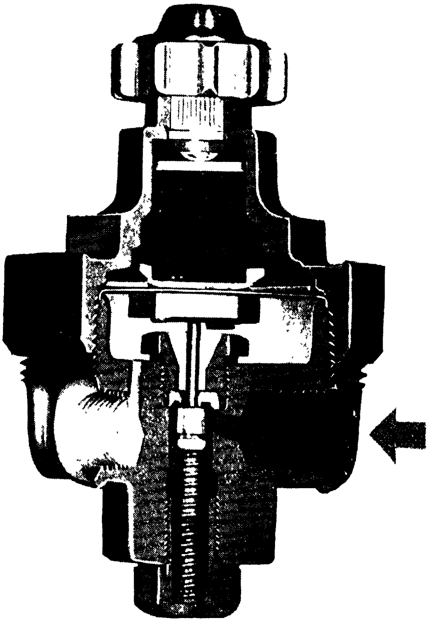


Figure 239. The cylinder pressure (red) enters the regulator at the right. The valve mechanism is controlled by a stem which touches, but is not connected to the diaphragm. The low pressure gas (yellow) is the gas supplied to the torch. The adjustment screw (top) is used to vary the pressure supplied to the torch

(Courtesy of: Victor Equipment Company)

oxygen regulators, acetylene for acetylene regulators, or carbon dioxide for either or both of them. A regulator is usually tested in the following manner. The rough test consists of mounting the regulator on the cylinder with the adjusting screw turned all the way out; then open the cylinder very slowly. Watch the low pressure gauge; if it starts to build up, close the cylinder valve quickly. Then turn the regulator in to permit a certain pressure flow of gas. Stop the flow of gas by capping the outlet of the regulator (hose connection) and then note the amount of increase pressure on the low pressure gauge. If this pressure increases more than 2 or 3 pounds above the flowing gas pressure, either the nozzle fitting, or the stem is leaking very slightly, or the parts are warped out of line. If the gas pressure creeps up steadily, it indicates that the moving parts are frozen within the guides, or that the valve is leaking badly. Occasionally after assembly, the regulator indicates a leaking valve. However, by tapping on the body of the regulator it will immediately start to function correctly. This action usually indicates the presence of dirt between the valve and the valve seat, which accidentally lodged there during the assembly of the regulator. This type of test does not indicate the smoothness of operation, or the accuracy of the setting of the regulator. This will be tested as follows: A small cylinder, with leak proof connections, should be attached to the outlet opening of the regulator (hose connection). This cylinder is equipped with an exhaust valve. After the regulator has been mounted on the high pressure cylinder, and after the small cylinder is attached to the regulator, the regulator adjusting-screw may be turned in slowly; for each turn of the regulator adjusting-screw there should be a corresponding increase in the small cylinder pressure. Any fluctuations in the small cylinder pressure indicate that the diaphragm is not moving smoothly, or that the valve or valve fitting is sticking or catching in its guide. With the low pressure part of the regulator under a pressure of 10 or more pounds, the body of the regulator should be tested for leaks, using a glycerine or soap solution, preferably a soap solution (NEVER USE OIL). Holding jigs for regulators form a very useful part of the welding repair equipment. The purpose of these jigs is to hold the body of the regulator while the parts are being assembled. A regulator usually consists of a cylinder that is clamped in a vise and has openings in the other end to receive the various shaped regulator bodies such as openings for the gauge connections, the cylinder connections, and the hose connections.

With a regulator body placed in this jig, the parts may be assembled conveniently and rapidly.

293. Repairing Gauges

The pressure gauges used as part of the oxy-acetylene welding equipment are exceptionally important to the welder. He must rely on their accuracy implicitly, both as a safeguard to his own life and as a means of informing him that his torch is adjusted accurately. It is, therefore, needless to say that these gauges must at all times give accurate readings. A welding equipment repair shop should have master gauges. These master gauges in turn

Figure 240. Replacing a regulator cylinder fitting
(Courtesy of: Victor Equipment Co.)

should be periodically calibrated by the use of a dead weight tester. By using these master gauges and by connecting the master gauge and the gauge being tested to a common cylinder, or a common regulator, a repair man may easily detect discrepancies in the gauge readings.

Simple inaccuracies of gauge readings may be easily corrected. However, such items as a buckled Bourdon tube or a ruptured Bourdon tube cannot be repaired. Also broken hair springs necessitate the replacement of the complete gauge. The minor adjustment of a gauge for slight inaccuracies is usually taken care of by changing the length of the linkage which connects the end of the Bourdon tube to the gear sector. A jeweler's eye piece and a set of jeweler's tools are exceptionally handy for this type of work. Slight errors in gauge readings may also be repaired by removing the

needle from its stem and setting it back on the stem in such a position as to correct the previous error.

To test for the accuracy of a gauge before returning it to service, the repair man proceeds as follows: The oxygen high pressure gauge (3,000 pound scale) must be tested with hydraulic pressure, using water or glycerine. The other gauges having a smaller scale reading, may be tested by using the cylinder pressures of the gases. The repair man should keep a quantity of gauges and replacement parts on hand to replace those gauges which have become injured in service. A complete range of sizes varies from the 2½″ diameter to the 4½″ diameter gauge and from the 0 to 30 lb. gauge up to the 0 to 3,000 lb. gauge.

294. Repairing the Arc Welding Generator

Any repair of arc welding equipment is best performed by local electric shops, or by shipping the parts needing repair back to the manufacturer. The local repair man, however, can perform certain functions to keep the arc welding machine at its peak of efficiency.

First, it is extremely important that the brushes and the commutator of an arc welding generator be kept in perfect condition. It is also important that the pressure of the brushes against the commutator be accurately measured and adjusted for the correct tension. The welding equipment repair man should, therefore, be capable of turning a commutator on a lathe and he should also be able to fit brushes to the commutator accurately. The spring pressure of the brushes against the commutator should be carefully measured, using a smallsized, spring scale. This tension should be tested at the point where the spring pressure presses on the brush. As the size of the brush determines the spring tension, secure the recommended pressure from the manufacturer. The brushes should fit on the commutator so that full surface contact is obtained. This is done by placing fine sandpaper (2/0) on the commutator with the sanding surface out and then putting the brush in its retainer. Slowly revolving the commutator will sand the end of the brush into a true fit on the commutator which should be turned only in the direction it runs when the generator is in use.

The lubrication of the motor and generator bearings is dependent on the type of bearing used. The more recent types use ball bearings which should be cleaned thoroughly and regreased once a year. When cleaning a ball or roller bearing never use an air stream to dry the bearing after washing out in gasoline. This practice is

dangerous and the bearing may be ruined. The maximum clearance or play recommended is approximately .001″ in these bearings.

295. Repairing Arc Welding Machine Accessories

Some parts of the arc welding apparatus which occasionally need checking are:

1. Ammeter
2. Voltmeter
3. Cables
4. Cable connections
5. Electrode holder
6. Overload relay
7. Magnetic starter

All arc welding machines are provided with ammeters and voltmeters, either built as one meter or as two separate meters. In those instances where the ammeter and voltmeter are the same meter (use the same pointer or needle), it is necessary for the operator to manipulate a switch button to change the meter reading from a voltage reading to an amperage reading. The dial is calibrated with two scales, one is the voltage and the other the amperage. Occasionally the meters read from 0 to maximum both ways, but usually the meter swings only in one direction. For example, some voltmeters read 100 volts to 0 volts to 100 volts, and the ammeter reads from 400 amperes to 0 amperes to 400 amperes, but the most popular type usually reads from 0 volts to 100 volts and the same meter, 0 amperes to 400 amperes. As previously explained, the voltmeter registers both when the arc welding machine is running and when it is not being used. The welding arc must be operating, however, before the ammeter reading may be taken.

The voltmeter, when indicating the open circuit voltage gives only a rough approximation of the capacity of the machine. However, the closed circuit voltage is much more important. It is a very good policy for the operator to know at all times what the ampere reading of the machine is, when doing any particular welding task. He may obtain this reading by striking an arc in a protected booth while he is standing in front of the machine away from the arc to observe the ammeter reading and while the arc is being maintained. It is essential that the arc be of the correct length in order that the reading be the correct one and not be misleading. The longer the arc the less the ampere consumption, while the shorter the arc the more the amperage. By having the electrode grounded and then by drawing an arc to the proper length, the variation of ampere flow will be as high as 50 amperes showing that it is essential that the arc be of the correct length. *Figure 241.* Before one may rely entirely on the meter readings, it is essential

that the accuracy of the meters be checked; this may be done by means of connecting master meters to the same machine and by checking the reading of the two while the machine is in operation. This may best be done by securing the services of a local power electrical engineer.

The cables and the cable connections for arc welding are very important. The diameter of the cables determines the efficiency of

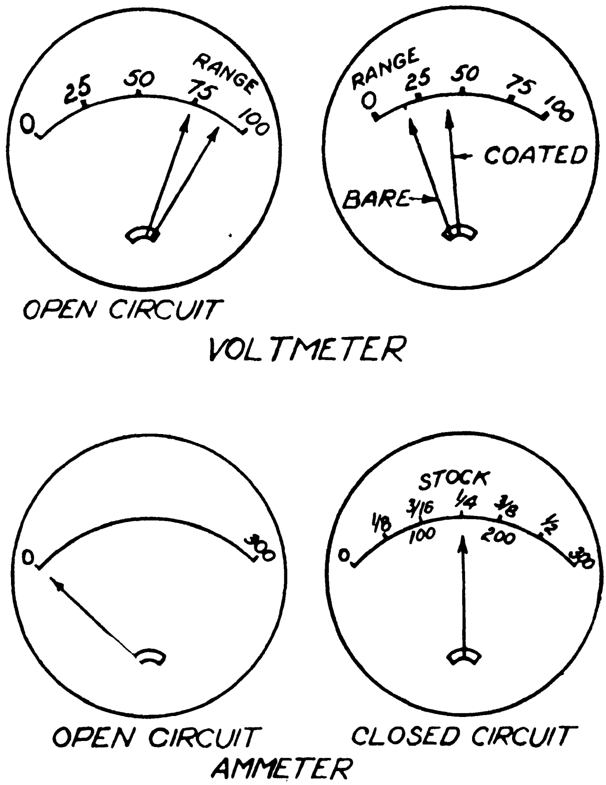


Figure 241. Typical arc welding meter readings

the electrical conductor. The larger the cable, the more current the cable can carry and the less resistance. On this same basis, the longer the cables the larger the cables should be. If too small a cable is used, the resistance to current flow becomes so large that the efficiency of the machine is destroyed. This results in very poor arc welding. Chapter 3 lists the various cable diameters for various current loads and for different lengths of run. In addition to the current carrying capacity of the cables, the connections where

the cables are fastened to the arc welding machine, to the electrode holder, and to the ground are very important.

To test the efficiency of the cables and the connections, the operator may proceed as follows: Start the machine and adjust it to the

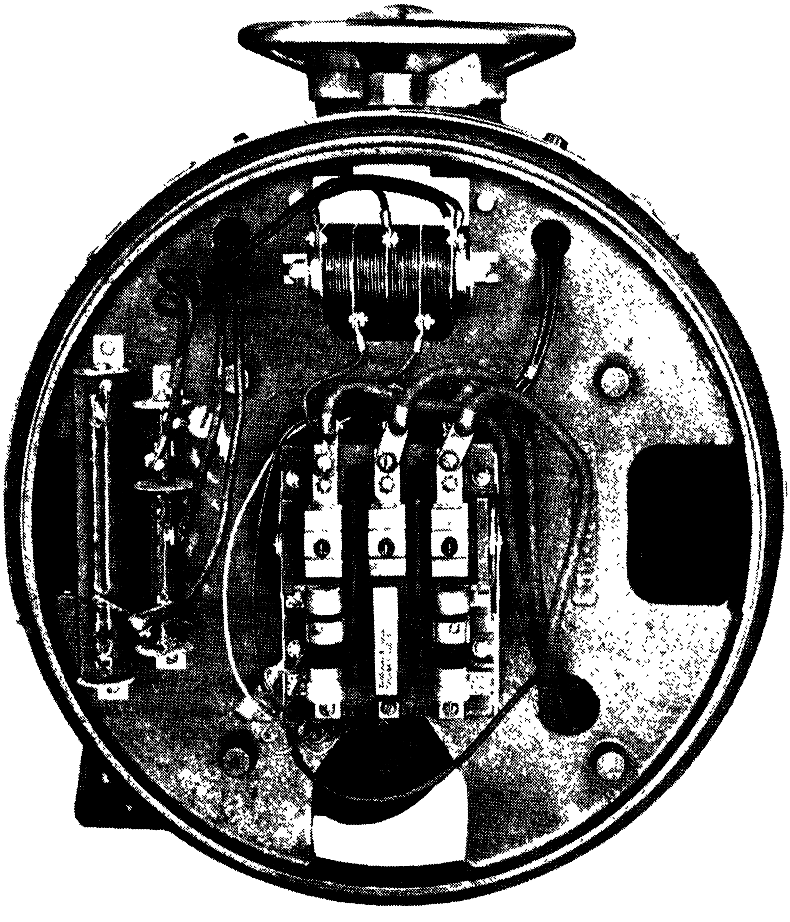


Figure 242. An overload relay, resistors, rectifier, and starter
(Courtesy of: Air Reduction Sales Company)

medium capacity of the unit. Ground the electrode holder securely to the table or to the article to which the ground cable is fastened. Record the reading of the ammeter and the voltmeter. Next, use a large sized cable of very short length, connect the positive and negative leads of the generator to each other (disconnect the regular

cables). This eliminates the cable runs. Start the machine and record the new voltage reading and ammeter reading. The difference in the readings determines the efficiency of the cables and connections. If the discrepancy is too large, the cable should be overhauled and new connections should be made. However, small differences in the reading should be neglected inasmuch as the cable runs cannot be made 100% efficient. *Figure 242.* The connections where the cables are fastened to the machines and to the ground are usually made with a large copper lug. The cable is soldered to this lug. This soldering must be carefully performed or a very inefficient joint will result.

To solder a lug to a cable properly proceed as follows: Heat the lug to a temperature sufficient to melt solder.

The cavity in the lug into which the cable end is to slip should then be filled with solder, after some solder paste has been put into the lug cavity to clean it chemically. After the solder has been worked until it wets the inner cavity surfaces, the excess solder is removed and the cable which has been cleaned with sand paper and soldering paste is inserted into the cavity. The two are then reheated to make the solder fuse. The soldered connection is then cooled, preferably by quenching in water.

Practically all arc welding machines are provided with a device which will stop the power supply if the motor starts to consume more current than it should. These overload relays consist of a heating coil through which part or all the electrical current is passed. This control is of sufficient size to carry any normal welding load without becoming overheated. However, if too much current attempts to pass through the wire, the temperature rises to the point where it will either melt some of the solder and release a trigger device which will open the electrical circuit, or the heat will bend a bimetal strip which, upon bending, actuates a trigger device to interrupt the electrical circuit. These devices are provided with means by which the operator may reset them by pulling a string to pull the trigger back in place, or by pressing a button. These devices offer very little trouble unless the heating element is pressed too close to the solder or to the bimetal strip which it actuates. Also the contact points, which the trigger device manipulates, may become corroded, resulting in overheating and an inefficient current supply.

Inasmuch as the average welding motor size varies between 10 H.P. and 15 H.P., it is inconvenient to start the motor by using an ordinary knife switch or button switch. This type of switch would

arc excessively. The machines are equipped with a magnetic starting apparatus which is controlled by a simple push button control. This magnetic starter consists of a large point contact switch usually of three point contact construction. The switch must be operated with considerable snap action to eliminate the arcing. To operate with snap action an electro magnet is used to pull the contact points into place. When the operator presses the starting button, a small quantity of electrical current is passed through an electro magnet. This electric magnet immediately pulls a soft steel laminated steel body which is connected to the moving part of the large trigger contact switch, and when magnetized completes the electric circuit to the motor. It may be of interest to know that practically all arc welding motors use three-phase current and, therefore, the motor is not provided with brushes or centrifugal switches. The motor, therefore, needs only occasional cleaning and oiling.

296. Summary

In reviewing the previous paragraphs in this chapter, these fundamental factors are outstanding in importance.

1. A certain minimum amount of equipment is necessary for oxy-acetylene welding and arc welding.

2. In order to perform a complete service, several kinds of accessory equipment are needed namely: pre-heating furnaces, cranes, power grinders, etc.

3. Welding equipment should be kept in first class condition for both economy and safety.

4. If the size of the shop warrants it, the repair equipment shop is an essential part of the factory. However, the person or persons doing the repair must be thoroughly trained and skillful or a dangerous situation will arise.

5. If a specialist cannot be employed it is best to send all shop welding equipment to a central repair shop which specializes only in this work.

6. All repairs on oxy-acetylene equipment must be made with extreme accuracy to insure safety.

7. All repairs on arc welding or electric resistance welding must be carefully performed with emphasis on safety. The danger of high voltage cannot be over emphasized.

297. Review Questions

1. Describe the different types of welding shops and welding equipment repair shops.
2. Name some fundamental functions of a preheating furnace?
3. What type of preheating furnace is the most popular?
4. Which is preferred in a welding shop a partable crane or a portable welding outfit?
5. How are jigs and fixtures used in welding?
6. Describe two uses of a power grinder in the welding shop.
7. What parts of a pressure regulator need frequent repair?
8. What materials are regulators and torches mostly made of?
9. How is a leaky regulator valve detected?
10. What is the most common method of fastening the diaphragm to the regulator body?
11. How may a buckled diaphragm be detected?
12. When assembling a regulator, should the adjusting screw be turned all the way into the bonnet or all the way out?
13. Why isn't oil used for lubricating oxy-acetylene parts?
14. Why is it important not to mar the surface of the mixing chambers?
15. What is the result of particles partly clogging the tip orifice?
16. What lubricant may be used on oxy-acetylene equipment?
17. What may be the result of a bellmouth tip orifice?
18. What material may be used to seal the pipe threads?
19. What is the result of a loose connection in an arc welder?
20. How may one determine if the commutator brushes do not fit the commutator correctly.
21. What is the harmful result of a dirty connection in an arc welding generator circuit?
22. What method is used to reverse a generator?
23. What method is used to shape the generator brush to a correct fit quickly?
24. What is the material that insulates commutator bars, and how is it removed?
25. What is the difference between voltage and amperage?
26. Do all arc welding machines have both ammeter and voltmeter?
27. What is the average voltage drop on an arc welder?
28. What are some of the causes of an excessive voltage drop?
29. What is the result of excessive voltage drop?
30. What is the recommended method for fastening the cables to the cable lugs?

CHAPTER XIX

MODERN WELDING, BRAZING AND SOLDERING APPLICATIONS AND EQUIPMENT

298. Inert Gas Arc Welding Principles

An important new welding technique has been developed during the past ten years. Basically, it consists of striking an arc between the base metal and a tungsten electrode in an atmosphere of inert gas (helium or argon) and applying the filler rod (when necessary) in a manner somewhat similar to gas welding.

The purpose of using this inert gas is to exclude oxygen from the high temperature molten metal. It also keeps other active elements existing in the atmosphere away from the molten metal. By elim-

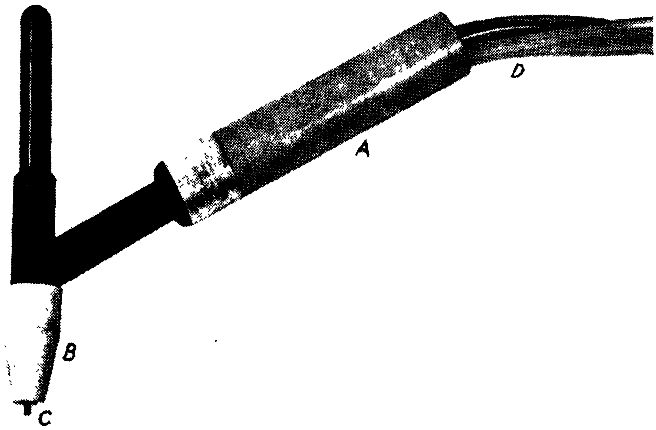


Figure 243. An inert gas arc welding torch: A. handle, B. porcelain cup, C. electrode, D. argon gas line, water-in line and electric cable
(Courtesy of: Linde Air Products Company)

inating oxidation and other impurities, welds are possible on metals which are impractical or very difficult to weld with the usual arc welding methods.

299. Inert Arc Welding Gases

Helium was the first inert gas used for this process. The most simple application consisted of striking an arc between the base metal and a tungsten electrode. This process is known by various names such as inert arc welding, tungsten arc welding, Heliarc, Heliweld, and the like. The electrode is mounted in a ceramic cup or a water-cooled cup which controls the flow of inert gas around

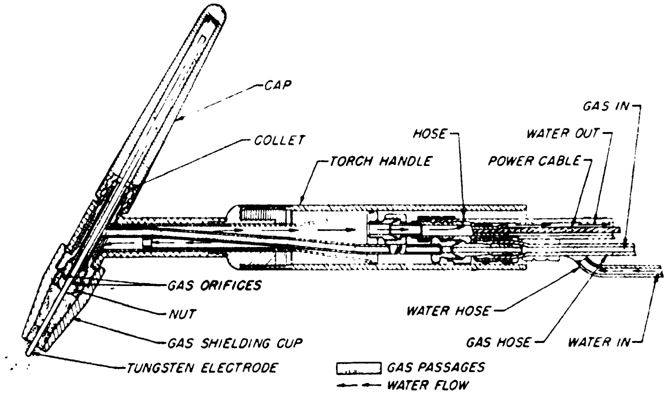


Figure 244. A sectional view of an inert gas arc welding torch
(Courtesy of: Linde Air Products Company)

the arc and molten metal. The filler rod is fed separately, as is done in gas welding, except in the automatic process. *Figure 243.*

Argon gas is also used in the inert-gas arc welding process. It is available from manufacturers of oxygen in most cases. Argon is

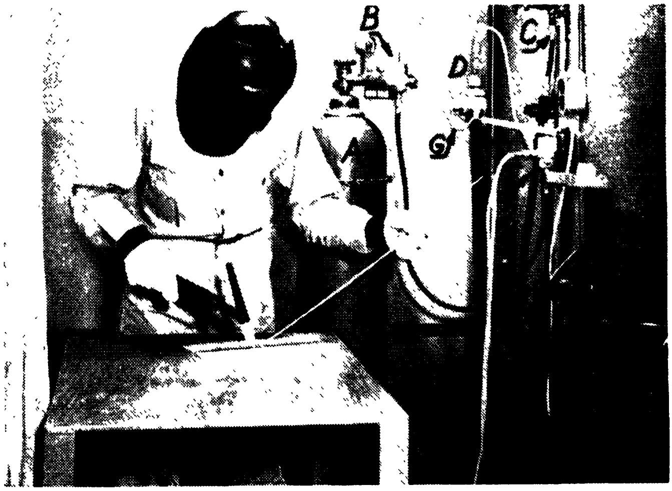


Figure 245. A complete manual inert gas arc welding station: A. the argon cylinder, B. the pressure regulator and flow meter, C. Water-in, D. Water-out, E. leads to the arc welding machine, F. the argon and water flow control valve operated by electrode holder hanger lever G
(Courtesy of: Linde Air Products Company)

heavier and diffuses more slowly than helium; therefore about ⅓ as much argon is needed by volume as compared to helium. The equipment required for either gas is very similar. *Figure 244.*

300. Inert Gas Arc Welding Equipment

The complete station consists of the torch (water cooled), the combination cable (electrical, inert gas, and water), a helium or argon cylinder (app. 240 cu. ft. at 2000 lbs. per sq. in.), a pressure regulator, a flow meter, control valves to control water flow and argon flow, a D.C. (usually) or an A.C. arc welder with high frequency stabilization. *Figure 245.* The argon equipment is es-

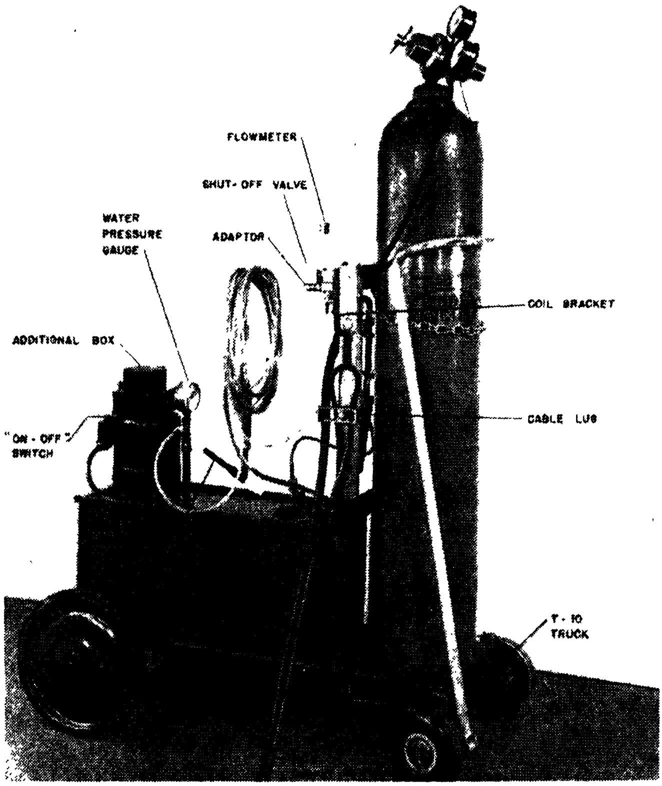


Figure 246. A portable inert gas arc welding station. This unit is complete as shown except the welding current source and a 100-Volt A.C. supply. It uses a water tank and circulating pump to improve portability
(Courtesy of: Linde Air Products Company)

sentially the same as oxygen equipment (cylinders, regulators, hose, etc.). The water circuit should also include a water strainer and a pressure regulator. *Figure 246.*

301. Inert Gas Arc Welding

The welding procedure is very similar to gas welding. The tungsten electrode is usually held at 15° angle from the vertical, and the torch is moved in the direction opposite the tilt angle. *Figure 247.*

Preparation for welding consists of first cleaning the metal and then preparing the edges. Standard 60° vees are used for most joints of more than 3/32″ thickness. The joint should be backed, if possible, to exclude oxygen and other impurities in addition to promoting better fusion through the metal. Other metals, carbon blocks, or an argon stream can be used for backing. *Figure 248.*

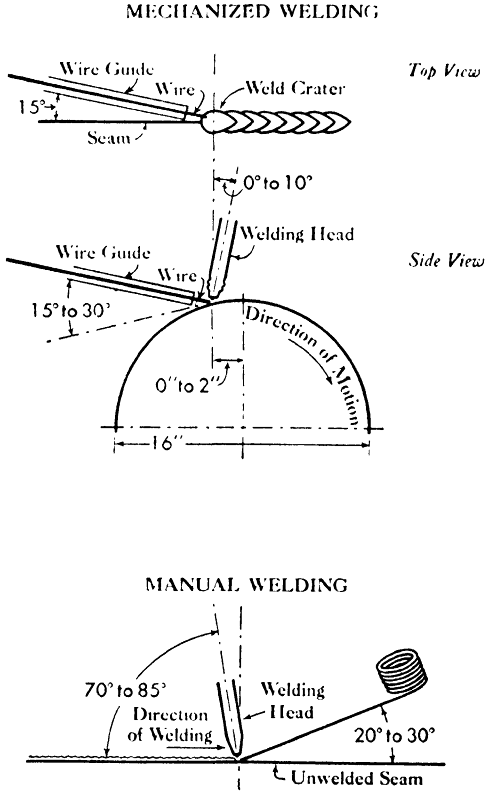


Figure 247. Positioning the torch and filler rod for both mechanized and manual inert gas arc welding
(Courtesy of: Aluminum Company of America)

Adjust the station for tungsten electrode amperage as shown in *Figure 249.*

The amperage for the metal thickness being welded is very similar to standard arc welding practice (see *Figure 48*). The electrode cup size must be varied with the electrode size, and consequently the current required changes. Always follow the manufacturer's recommendations.

Adjust the water flow and the inert gas flow. The water flow

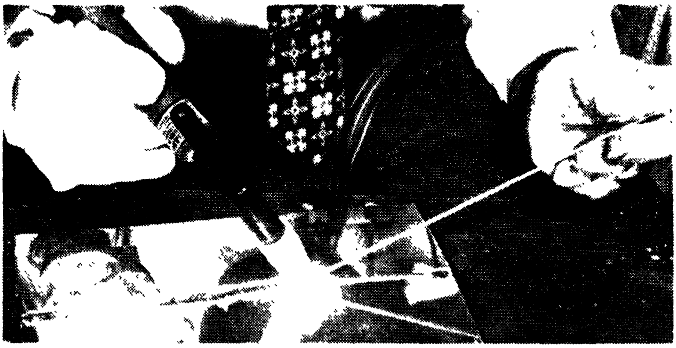


Figure 248. An inert gas arc weld. Note the position of the electrode holder and the filler rod. The material is aluminum.
(Courtesy of: Linde Air Products Company)

varies between 12 to 23 gallons per hour. The argon flow when welding steel is 8-10 cu. ft. per hour for .035″ thickness up to 3/32″ thickness steel. For 1/4″ thickness cast iron, use 16 cu. ft. per hour. For copper between 1/16″ to 1/4″ thickness, use 15 cu. ft. per hour. For stainless steel 1/16″ to 1/8″ thickness, use 11 cu. ft. per hour; and for 3/16″ to 1/4″, use 13 cu. ft. per hour.

TUNGSTEN ELECTRODE CAPACITIES

	Current		
Electrode dia. (in.)	A.C.	D.C.-St. Pol.	D.C.-Rev. Pol.
.040	10-60	10-80	
1/16	40-120	60-150	10-20
3/32	100-160	150-250	15-30
1/8	150-210	250-400	25-40
5/32	190-275	400-500	40-55
3/16	250-350	500-800	55-80
1/4	300-490	800-1100	80-125
5/16	450-600		
3/8	550-700		

Figure 249. A table of amperage settings for various tungsten electrode diameters
(Courtesy of: Linde Air Products Company)

The tungsten must be clean. It must have good electrical contact with the collet, and it should be adjusted to extend 1/8″ beyond the end of the cup. It is extremely important that the helium or argon hose and all the connections be perfectly tight because air or moisture in the inert gas would be harmful to the weld.

To start the unit, use the following steps: First, be sure that the argon and water are flowing. These fluids are controlled either by manual valves built into the electrode holder or torch hanger or are controlled automatically. *Figure 245.* Strike the arc, if using

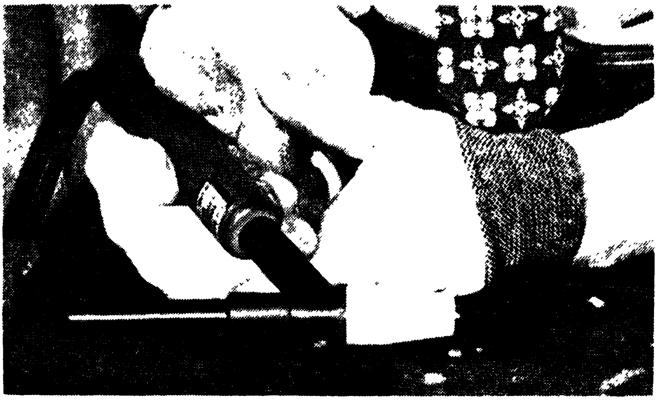


Figure 250. Holding the inert gas arc welding torch before starting the arc.
(Courtesy of: Linde Air Products Company)

A.C. current with high frequency stabilization, by holding the torch horizontally over the metal starting block or work. (Do *not* use carbon as a starting block, as tungsten carbide may be formed on the end of the tungsten electrode.) Then very quickly tilt or swing the torch to the upright position with the electrode reaching a point

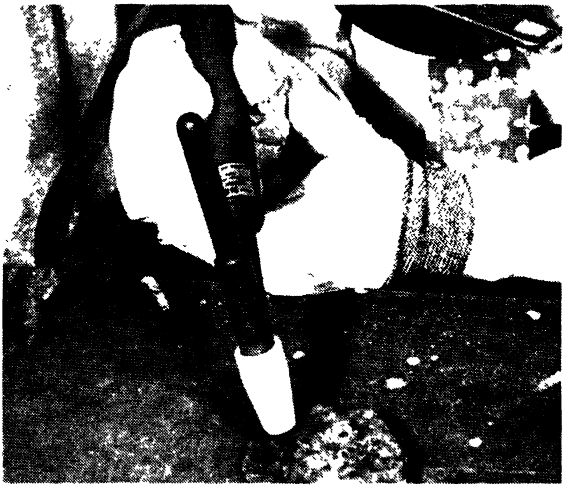


Figure 251. Proper position of the torch after the arc has been struck
(Courtesy of: Linde Air Products Company)

1/8″ above the metal. With alternating current, the arc will jump this gap after it is started. *Figures 250* and *251*. If D.C. is used, the tungsten must be touched to the metal and then withdrawn.

While welding, use a small circular motion and make a small puddle in the spot where the weld is to begin. If filler rod is being used,

move the torch arc to the back edge of the puddle, insert the filler rod in the front edge of the puddle, and then bring the torch forward to move the puddle a ripple length along the direction of the weld. Hold the filler rod at a very flat angle (app. 15°). To stop the arc, tilt the torch sharply 90°. Always keep the gas flowing until the tungsten is cool, or the tungsten will become corroded and wear too rapidly.

The inert gas arc torch can be used to produce both flat and vertical welds. Progress should be downward when welding in a vertical position.

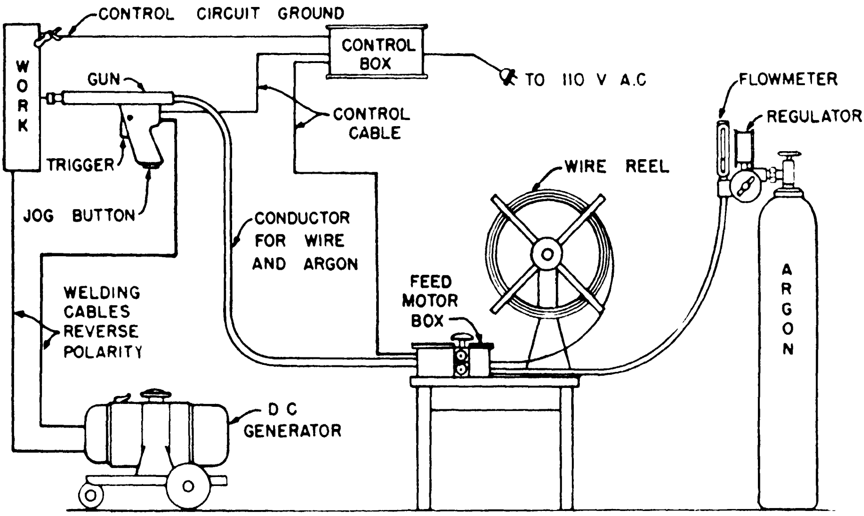


Figure 252. An automatic inert gas arc welding machine
(Courtesy of: Air Reduction Sales Company)

One should use a dark shade lens, (#12 to #14) when inert gas arc welding because the arc is more exposed, and is very intense. The operator must also be very careful to protect his skin from the arc rays.

The machine must be kept in excellent condition for best results. Repair water leaks immediately as wet equipment or a wet floor increases the chance of electrical shock. The secondary voltage of the machine, or the high frequency voltage, should be disconnected while working on the equipment, but not welding.

302. Automatic Inert Gas Arc Welding

Automatic machines have been developed to do inert gas welding. The automatic method uses a coil of electrode material fed through the inert gas cup instead of using a tungsten electrode. *Figure 252.*

Welding aluminum by the inert gas arc is very successful. Welds in the horizontal, vertical, and overhead positions are possible. One of the most popular applications of this process is the production of sound welds in aluminum in these positions. Alternating current with an argon atmosphere is most commonly used. *Figures 253* and *254*.

The aluminum should be cleaned prior to welding. Either mechanical cleaning or an etch cleaning or both may be used. Steel wool

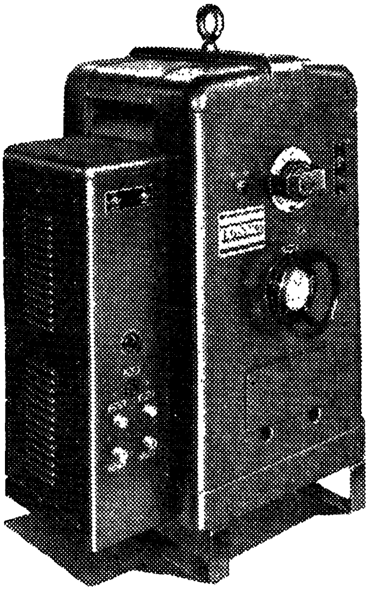


Figure 253. An A.C. transformer type arc welder specially designed for inert gas arc welding. This machine has a high frequency arc stabilizer, also automatic water and gas valves
(Courtesy of: Hobart Brothers Company)

gives good results. Also a five minute immersion in a 10% nitric acid and .25% hydrofluoric acid solution gives satisfactory cleaning. Be sure to follow the etching with a hot water rinse.

303. Inert Gas Spot Welding

A special application of the inert gas arc welding system is the inert gas spot weld. By correct timing and using a special torch, this method is used to melt one member of an assembly and fuse it to the underneath member in a "spot." *Figure 255.* This device removes the need to reach both sides of an assembly.

304. Stainless Steel Welding

There are a large number of different steels known as stainless

steels. All have varying amounts of chromium or a combination of chromium and nickel in them. These steels are corrosion resistant, retain a good clean appearance, and have good physical properties. The American Iron and Steel Institute has classified these alloys by number, and the specifications are as shown in *Figures 256, 257* and *258*.

There are three general classifications of Stainless Steels:

1. Austenitic
2. Martensitic
3. Ferritic

DATA FOR TUNGSTEN-ARC WELDING OF ALUMINUM

Alternating Current—Argon Gas

Thickness, inch	No. passes	Current, amperes	Tungsten diameter, inch	Argon volume cu. ft./hr.[1]	Cup opening diameter, sixteenths	Filler wire diameter, inch
0.051	1	70	1/16	12	6-7	1/8
0.064	1	80	3/32	14	7	1/8
0.081	1	90	3/32	14	7	5/32
0.101	1	120	1/8	15	7-8	5/32
0.125	1	140	1/8	15	7-8	5/32
0.187	1	160	1/8	15	7-8	3/16
0.250	2	220	3/16	20	8	3/16
0.375	2	300	1/4	24	8-10	1/4
0.500(2)	3-4	400	1/4	24	10	1/4
1.000(2)	10-14	500	5/16	30	10-12	5/16
2.000(2)	20-30	600	5/16	30	10-12	5/16

[1] Multiply reading on oxygen flowmeter by 1.5 to convert from liters per minute to cubic feet per hour of argon gas.
[2] Preheat to 400°F.

Figure 254. A table of inert gas arc welding settings for aluminum welding. (Courtesy of: Aluminum Company of America)

See *Paragraphs 235* and *256* for further information concerning the iron-carbon properties of these metals. *Figure 195.*

Austenite is a physical condition in plain carbon steel that exists only at temperatures above 1200° to 1300° F. It is a solid solution of Fe_3C in iron.

It has been found by adding chromium and nickel to the steel that this austenite form can be retained in the metal as it cools down to room temperatures, if the metal is cooled quickly. Therefore, any steels with alloying elements that enable the existence of austenite at room temperature are called austenitic steels. Stainless steels of

the 300 series (chromium and nickel) are a good example of austenitic steels. These steels do not harden by heat treatment, but rather by cold working.

As a result of research dating back to about 1935, chromium-nickel steel electrodes are now used to weld high tensile steels (low alloy) without a preheat or post heat being used. World War II necessitated a tremendous growth of this technique with the result that armor plate, etc., was very successfully welded with stainless steel (austenitic) electrodes.

Figure 255. A special inert gas arc welding torch used to produce "spot" welds on the structure inside an automobile body
(Courtesy of: Linde Air Products Company)

These austenitic steels are also non-magnetic or are very weakly magnetic. These stainless steels make good household appliance sheet metal parts. *Figure 256.*

When stainless steel was first welded using stainless steel filler metal, the welds sometimes had intergranular cracking (chromium carbide). To stop this action columbium and/or titanium is now added to the stainless steel. Titanium is proving the most popular. (American Iron and Steel Institute Series 321 and 347.)

The martensitic stainless steels have less than 14% chromium content and a varying carbon content. These steels are good for tableware, instruments, ball bearings, etc. These steels are harden-

able by heat treatment. They are also magnetic. *Figure 257.*

Ferritic stainless steels have a high chromium content and less than .15% carbon. They have a ferrite grain structure at room temperature and are not hardenable by heat treatment. *Figure 258.*

Gas welding stainless steel of the austenitic group is very practical, and is not difficult to do. The metal being welded must be carefully cleaned (stainless steel wool or a clean stainless steel wire

AUSTENITIC STAINLESS STEELS (Chromium and Nickel Alloys)

A. I. S. I. Series	% Cr	% Ni	% C	% Others
Type 301	17	7	.08-.20	....
302	18	8	.08-.20	....
304	18.5	8.5	.08 max.	....
316	17	12	.10 max.	Mo 2.5
317	17	14	.10 max.	Mo 3.5
347	18.5	10	.10 max.	Cb 10 x C
321	18.5	10	.10 max.	Ti 4 x C
308	20	11	.08 max.	Mn 2 max.
309	24	13	.20 max.	....
310	25	20	.25 max.	....
318	17	12	.10 max.	Mo 2.5

Figure 256. A table of austenitic stainless steels

MARTENSITIC STAINLESS STEELS (Straight Chromium of less than 14%)

A.I.S.I. Series	% Cr	% C	% Others
410	12	.15 max.	....
416	13	.15 max.	P.S. or Se .07 min. ZR or MO .60 max.
501	5	.10 max.	....
502	5	.10 max.	....

Figure 257. A table of martensitic stainless steels

FERRITIC STAINLESS STEELS (Straight Chromium of 14% or More)

A.I.S.I. Series	% Cr	% C
430	14-18	.12 max.
446	26	.35 max.

Figure 258. A table of ferritic stainless steels

brush), the joint must fit well to avoid gaps, and overlaps, the parts should be mounted in heavy, tight clamping fixtures. Stainless steel has a high (50% more than mild steel) co-efficient of expansion, and therefore warps very easily. Tack welds, one to two inches apart, are frequently used as an alignment aid. Stainless steel filler rod flux must be used. The austenitic stainless steel 18-8 is the easiest to weld. Some of these 18-8 steels have titanium added (AISI 321) while some have columbium added (AISI 347). The filler rod must also be of 18-8 stainless steel and it usually has columbium content to minimize intergranular cracking. Another popular stainless steel is the 25-20 series.

To weld, flux both the surfaces and the rod using a small clean brush. Clamp the joint pieces carefully in the fixture. Some welds may best be performed by first spot welding the pieces of metal together. Choose a tip size a little smaller than used for mild steel of the same dimensions. Hold the torch (neutral flame or very, very slightly carburizing) at a 60° to 80° angle, and as soon as a small puddle is formed feed the filler rod to this puddle. As soon as that spot is welded move forward very slightly, and repeat. Always leave the filler rod in or very near the puddle (front edge). Never lift the filler rod away or the oxides formed will injure the quality of the weld. Always remove the torch by pulling it away slowly so that flames may keep the last portion of the weld protected from the atmosphere until it has cooled somewhat. The control of the puddle in stainless steel is much more critical than with mild steel. A little too much heat and the alloy disintegrates.

The completed weld should be straight, even in width, slightly crowned, and evenly penetrated. The slight discoloration of the weld, and the metal adjacent to the weld is easily removed by buffing, and polishing.

Stainless steel may be more easily silver brazed than gas welded. A silver brazed joint is very strong if properly designed and made. The metal does not warp to any great extent because of the relatively low silver brazing temperatures, and a good color match can always be obtained. With stainless steel, a 45% silver alloy filler rod produces a good silver brazed joint.

It is easier to arc weld stainless steel than to gas weld it. All arc welding methods such as manual arc welding, automatic arc welding, atomic-hydrogen arc welding, and inert gas arc welding may be easily and effectively used in welding stainless steel. The electrode must match the type of stainless steel being welded. To obtain good, consistent results, one must follow the stainless steel manufacturer's, and the electrode manufacturer's recommendations exactly.

The American Welding Society has prepared identification numbers for a variety of stainless steel welding electrodes. For example, E 308-15 is for AISI 301 to 308 series, and is used in all positions EXXX-IX, and has a lime coating EXXX-X5 which calls for D.C. reversed polarity. Because there are at least seven main classifications for the austenitic steels, one should use great care when selecting the electrode to be used.

The electrodes usually have a columbium content to minimize intergranular cracks. The current settings are slightly lower, but the

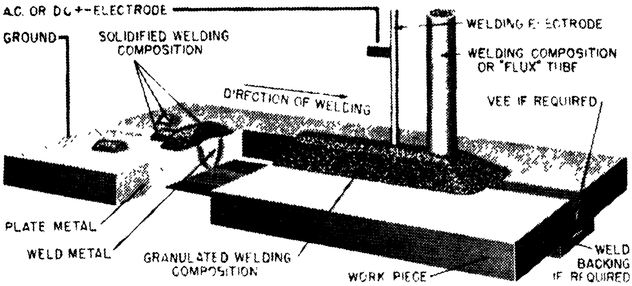


Figure 259. A diagrammatic view of a submerged arc weld in action
(Courtesy of: Linde Air Products Company)

electrode sizes are very similar to the choices for mild steel welding. D.C. reversed or A.C. current is used. AWS XXX-15 electrodes are used with D.C. reversed, and AWS XXX-16 electrodes are used with D.C. reversed or A.C. The electrodes must be kept dry and clean. The electrode coating must be free from cracks and chips. The welding procedure is almost identical with mild steel practice. The

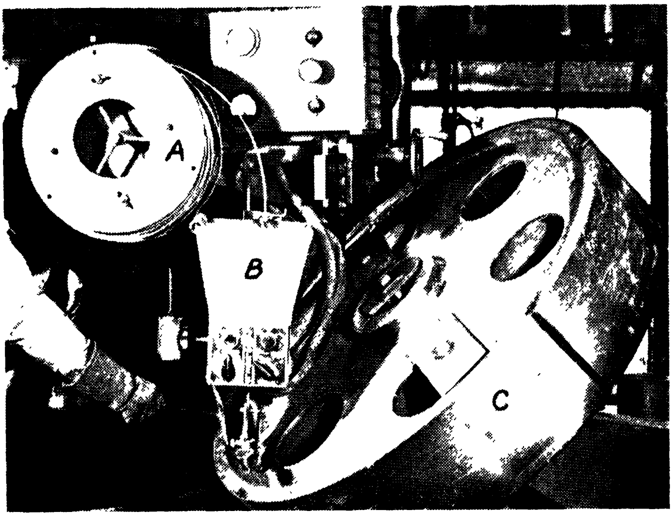


Figure 260. A submerged arc in action: A. Electrode reel, B. Flux hopper, C. The large wheel being fabricated is mounted on a positioner
(Courtesy of: Lincoln Electric Company)

same electrode position, crater appearance, electrode motion or weave should be used. It is advantageous to use as short an arc as possible.

Inert gas arc welding is particularly desirable with stainless steel. Strong, good looking welds may be obtained with a minimum of dis-

coloration and warpage. The metal behaves normally under the arc, and the filler rod may be added in a manner similar to gas welding.

Since the use of flux is not necessary with inert gas arc welding, no after-cleaning is necessary.

305. Submerged Arc Welding

During recent years (1940-1950) a new welding process has grown rapidly in popularity. It is known as the submerged arc welding process, and it has some outstanding advantages. It is very fast. There is no visible arc, no splatter; and the welds are of very high quality. *Figure 259.*

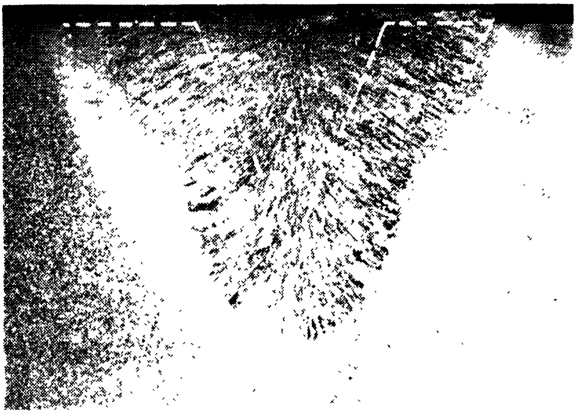


Figure 261. A two-pass submerged arc weld cross section. It has been etched to better show the weld areas. The dashed lines indicate the original plate preparation. The metal is 3¼″ thick and one may note by the grain refinement that the smaller pass was made first
(Courtesy of: Linde Air Products Company)

The method involves striking the arc between a bare electrode and the joint while both are buried in a granular flux (titanium oxide-silicate). *Figure 260.*

Some of these machines are able to produce single pass welds for butt joints up to 3″ in thickness, plug welds up to 1½″ in thickness, and fillet welds up to ⅜″ legs. *Figure 261.*

The American Welding Society defines a plug weld as follows: "Plug welding is a method of attaching a lining by welding it to the base plate through holes punched or cut through the lining. The holes which vary in size according to the thickness of the liner are filled with weld metal which bonds to the base plate and to the liner around the edges of the hole."

Bare electrodes up to ½″ diameter may be used. The current may be as high as 4000 amperes, and it may be either A.C. or D.C.

The typical machine has a power operated carriage with a universal variable speed motor to control the travel rate from 7 to 210 inches per minute. As seen in *Figure 262,* a hopper feeds the granular flux to the joint just ahead of the arc. As the arc is struck and the bead is formed, the heat generated melts the flux granules, and a portion of the flux fuses and covers the weld with an air tight slag that protects the weld until it cools. This slag is readily removed and the unused granules can be used again.

Since the arc is submerged and therefore not visible to the operator, the correct current setting is indicated by the ammeter reading

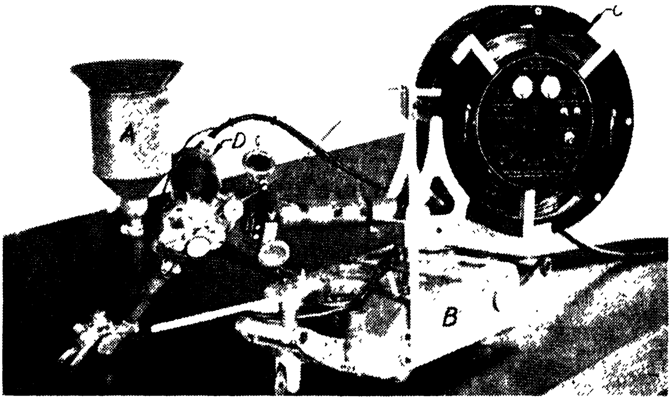


Figure 262. A submerged arc welding station. A. flux hopper, B. motorized carriage, C. Electrode reel and control panel, D. Electrode feed motor
(Courtesy of: Linde Air Products Company)

and the correct arc length is indicated by the volt meter reading.

This method is excellent for production jobs, and it is also used for large welding projects. The carriage may be used on a standard track, on a template track, or the carriage may be mounted on the metal being welded.

Some automatic submerged arc welders operate with two electrodes connected in series. In these machines the work is not grounded as in most arc welders, but instead the arc is formed from one electrode to the work and a second arc is formed from the work back to the second electrode. With this mechanism there appears to be less dilution (mixing of filler metal with base metal) than is the case with the single electrode type of submerged arc welding.

The bare electrode is furnished in coils, and the electric motor controls the rod feed. The controls for the process are all mounted on the machine, and a few adjustments enables the machine to be used for a large variety of jobs.

Submerged arc welding may also be done manually. *Figure 263.* A small hopper is built onto an electrode holder, and a combination electrode feed wire and cable is attached to it. The operator guides the electrode holder and is able to make very fast welds over straight or irregular joints.

306. Tool and Die Steel Welding

The use of stamping, drawing, and forging presses are an important trend in modern production manufacturing. The dies and tools used in these machines are capable of producing thousands of duplicate parts. Obviously these stamping, drawing, and forging tools and dies must be built exceedingly strong. They must be made very accurately, and they must hold their accuracy. They are usually

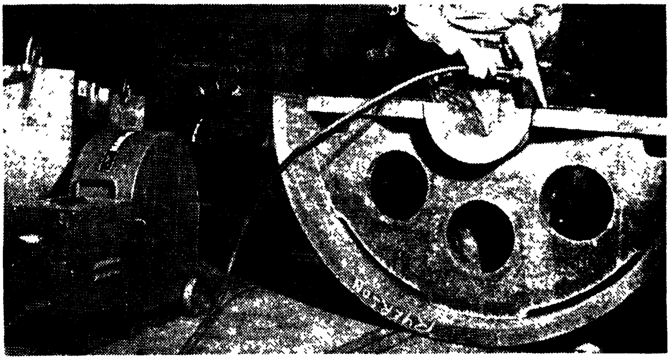


Figure 263. A manually operated submerged arc welding station. Since there is no visible arc there is little necessity for the operator to wear the usual arc welding protection clothing and helmet
(Courtesy of: Lincoln Electric Company)

made of some tool steel or a high carbon alloy steel, and are accurately shaped, heat treated, and ground. If a part of the tool or die wears or breaks, the production of a duplicate one is slow and very expensive. Tool and die welding makes it possible to reclaim many of these tools by rebuilding the worn surface or replacing the broken part. *Figure 264.*

307. Types of Tool Steels

There are many different alloys and trade brands of tool steels. However as far as the welder is concerned, it is only necessary for him to select the electrode to match the heat treatment required in

repairing any particular tool. There are four general heat treatment classifications which may be used. These are:

1. Water hardening tool steel.
2. Oil hardening tool steel.
3. Air hardening tool steel.
4. Hot working tool steel (ni-chrome steels as a base).

308. Tool Steel Welding Procedure

To weld tool steels the surface must be cleaned and occasionally shaped (ground) to best receive the electrode deposit. It is also

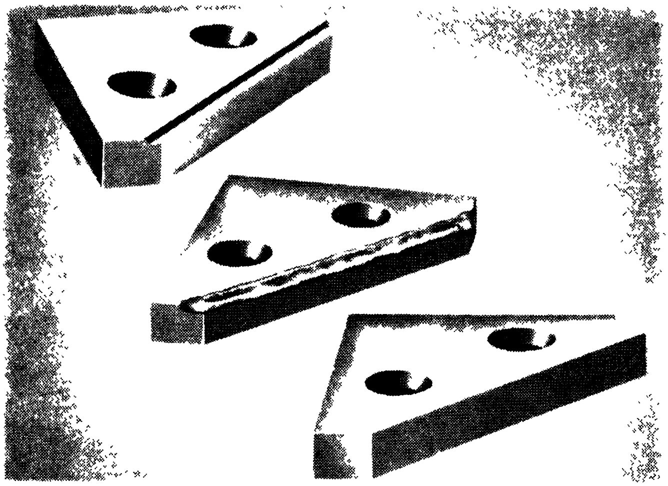


Figure 264. Water hardening shear blade ground, welded with oil hardening electrodes, ground to a cutting edge, and ready for use. It will last two to three times longer than the original blade
(Courtesy of: Welding Equipment and Supply Company)

good practice to pre-heat the tool or die. It is very important to deposit a minimum of metal and then peen the metal to relieve the shrinkage stresses. Finally, the job should be heat treated (hardened and drawn) *Paragraph 261,* according to the original specifications of the tool or die.

Some of the basic steps to be observed when welding tool steels are as follows:

1. Know the type of tool steel.
2. Use an electrode recommended for the type of steel to be welded.
3. Make the proper joint preparation.
4. Preheat, *Figure 265.*

5. Weld reverse polarity (never exceed the maximum draw temp.).
6. Heat treat the weld.

Tool steel electrodes are available in sizes ranging from 1/16" to 3/16".

The electrode deposit must contact 1/8" of surface width of the base metal. For large deposits a 1/8" thickness deposit is recommended except on draw and forming dies. *Figure 266.*

Weld in an uphill direction, if possible, as this position permits

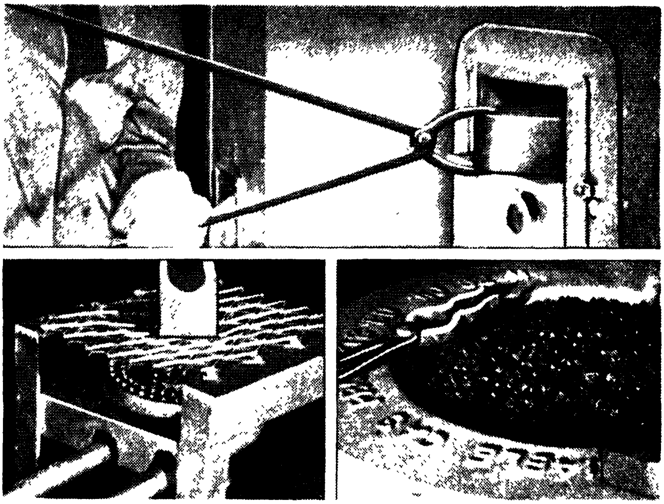


Figure 265. Shown are several methods used to preheat and post heat tool and die steels
(Courtesy of: Welding Equipment and Supply Company)

the slag to float to the rear of the crater. It is desirable to peen to relieve stresses in the deposit. *Figure 267.* A post heat treatment is necessary for maximum results. Use temperature indicating colors and cones to accurately determine the temperature. Large pieces require more time to complete the heat treatment than small pieces. In general use one hour per 1/8" thickness being treated. Size determines time.

The weld quality depends upon several factors as follows:

1. Type of steel.
2. Amount that the base metal mixes with the weld deposit.
3. Rate of cooling.
4. Pre-heat treatment.
5. Technique of welding.
6. Heat treatment after welding.

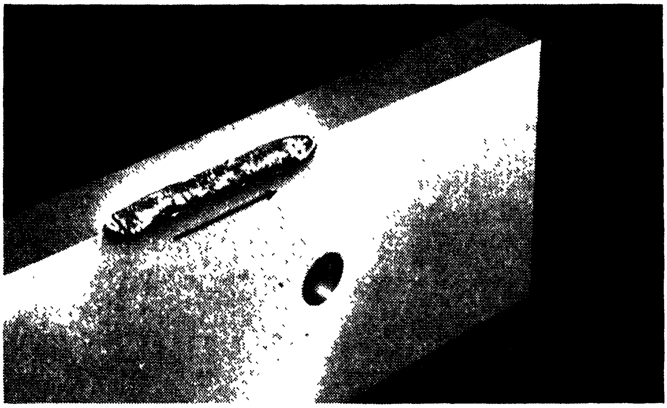


Figure 266. The procedure to be followed when depositing a tool steel electrode on the edge of a shear blade. Note that the bead is made first to the right, then to the left with a definite overlap where the two beads meet
(Courtesy of: Welding Equipment and Supply Company)

309. Tool and Die Steel Heat Treatment

It is practically impossible for the welder to identify the alloy of the tool steel or the type of heat treatment required; therefore careful records must be kept of the specifications for each tool from the time of manufacture or purchase. It is expected that the tool steel

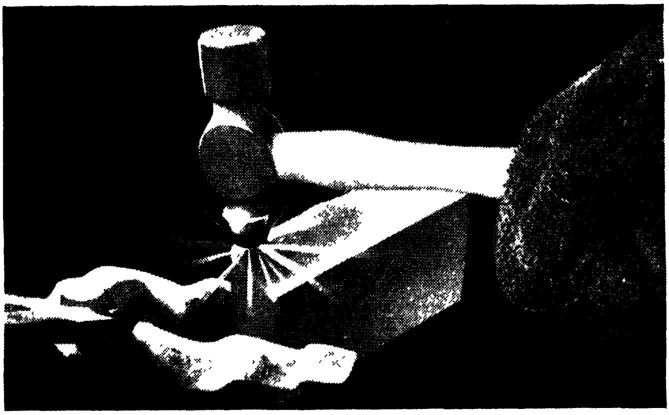


Figure 267. It is important for good results to peen the deposited metal to relieve the stresses set up by the deposited metal
(Courtesy of: Welding Equipment and Supply Company)

welder will be given this information before making a tool or die weld.

One of the most important factors in tool and die welding is the proper pre-heat and post heat. The temperature to which the metal

is heated is of vital importance as a few degrees too little or too much will prevent getting the proper results. Automatic furnaces with heat source controls and thermocouple temperature indicators

Figure 268. A temperature indicating crayon. This 200° F crayon has just produced a mark, first over a metal surface of 200° F or more, (the crayon mark melted) then over a part of the same metal cooler than 200° F (the crayon mark was not affected)
(Courtesy of: Tempil° Corporation)

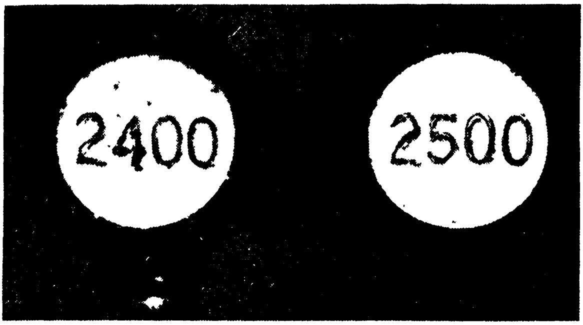


Figure 269. Temperature indicating pellets. The melting 2400° F pellet and the still solid 2500° F pellet indicates that the metal temperature is 2400° F + and less than 2500° F
(Courtesy of: Tempil° Corporation)

are best. However, their expense makes them practical only in the largest shops. An excellent solution for the small shops is the use of temperature indicators such as Tempil crayon, pellets, or liquid. *Figure 268.* These materials are obtainable in a great variety of temperatures. They will indicate temperatures in 12½°F steps, in the 113°F to 400°F range, and in 50°F steps in the 400°F to 2000°F range. The pellets are also obtainable in 100°F steps from 2000°F to 2500°F. *Figure 269.*

310. Electrode Classification

There are a large variety of welding electrodes on the market. They vary in type of metal and type or composition of the coating.

The American Welding Society has developed a series of identifying number classifications which is also approved by the American Society for Testing Materials. The meaning of the numbers is as follows: The letter "E" preceding the number indicates electrode as contrasted with the letter "G" indicating a gas welding filler rod. The first two digits represent the tensile strength when stress relieved, i.e., 60 means 60,000 and 100 means 100,000. The second to the right digit indicates the position of the joint: 1, all positions; 2, flat and horizontal weld on a vertical surface fillet position; 3, flat position only. The first digit from the right indicates the type of coating.

For example, E-6010 has a stress relieved tensile strength of 60,000 lbs. per sq. in. (60XX). It may be used in all positions (XX1X) and has the organic coating (XXXO). This type of electrode has deep penetration properties, but will undercut easily. The E-6011 is similar to 6010, but the (XXX1) designation means the coating has an arc stabilizer included, and the electrode can therefore be used with A.C. The organic coating means at least 30% cellulose material. Calcium and/or potassium compounds are the arc stabilizers in most E-6011. All of the 60XX electrodes have the same steel composition.

The E-6012 electrode produces nice looking beads in the flat position. It is popular for poor fit joints and is very fast (the coating can stand more current without failure). The penetration is only average. This popular electrode is good for the higher carbon steels and has very little splatter. It has titania or rutile coatings (XXX2).

The E-6013 electrode is used for sheet metal work. The arc is easily maintained (as the XXX3 indicates ionizing agents in the coating). The deposited slag peels away; therefore some operators call this electrode the self-cleaning type. Those electrodes which have this feature are sometimes called E-6013B electrodes. The E-6013B has a very fluid puddle and is used for fillet welding extensively.

The low hydrogen electrode (a lime-ferritic coating) is also a E-60XX type electrode (E-6015 and E-6016).

The E-70XX to E-100XX numbers are alloy electrodes. One must be certain that the manufacturer's recommendations are followed exactly for good results.

311. Typical Electrodes

AWS-ASTM Number	Position	Use	Application	Typical Brand Names
E 4510	all		Bare or dusted	Sulkote Kathode, Stable Arc
E 4520	all			
E 6010	all	Penetration	d.c. reversed	SW-10, Blue Devil, Vertex W-27, Fleetweld 5 Bluedac, W-26
E 6011	all	Penetration	d.c. reversed or a.c.	Fleetweld 35, Type A Gray Devil 2, Genex
E 6012	all	Production	d.c. straight or a.c.	Fleetweld 7, SW-11 Graydac, W-25
E 6013 A	all	Sheet Metal & Fillets	d.c. straight or a.c. on light gage	Fleetweld 47 Black Devil, W-24
E 6013 B				
E 6015	all		d.c. reversed	Plusalloy 70
E 6016	all		d.c. reversed & a.c.	
E 6020 H fillets	F		d.c. straight or a.c.	Fleetweld 10, SW-35 Red Devil, Cresto
E 6030	F		d.c. or a.c.	Fleetweld 9, SW-20 Blue Devil 85, Neolex
E 7010	all			Shield Arc 85, SW-75
E 7011	all			Arico 382, W-56
E 7012			d.c. or a.c.	Black White, Wilson S 82
E 7016	all	low hydrogen	d.c. or a.c.	
E 7020	F & H	Moly	a.c. straight a.c.	Black Devil 75, W54 Fleetweld 11RT, SW-73 Red Devil 75
E 7030	F	Moly	d.c. reverse or a.c.	Fleetweld 9, HT
E 8010	all	Moly	d.c. reversed	General Electric, W58
E 8011	all	Moly	d.c. reversed	
E 8016 (low hydrogen)	all	Nickel Alloy	d.c. reversed	75LP
E 8020	all	Moly	d.c. reversed	General Electric, W66
E 9010	all	Moly	d.c. reversed	General Electric, W66
E 9011	all	Moly	d.c. reversed	
E 9020	all	Moly	d.c. reversed	General Electric, W67
E 10010	all	Moly	d.c. reversed	Shield Arc 100, SW96
E 10012	all	Moly	d.c. reversed	Planeweld, 1
E 10016 (low hydrogen)	all	Nickel Alloy	d.c. reversed	P & H, 17
E 10020	all	Moly	d.c. reversed	SW101
E 12016 (low hydrogen)	all	Nickel Alloy Aircraft	d.c. reversed	P & H, 21

312. Electrode Care

It is very important that the user follow the electrode manufacturer's recommendations as to amperage, base metal preparation, welding technique, welding position and the like. The electrodes must not be used after being exposed to dampness because the steam generated by the heat of the arc causes the coating to be "blown" away. All questionable electrodes should be "baked" at 250°F for several hours. Because of the similarity of appearance of electrodes that are much different in welding properties, it is important to label and store them in carefully marked bins. Use masking tape to bind electrodes and label with scotch tape when putting them in storage. Most electrodes represent considerable cost, and therefore loss of identification may mean much loss in time and money.

If an electrode is used beyond its amperage rating, the electrode will overheat; and the coating will crack, thus spoiling the rod. The excess current will also cause considerable splattering of the molten metal.

The electrode coatings vary considerably. Their main function is to prevent the atmosphere from reaching the hot liquid metal. The coatings may also contribute to the addition of certain elements (metallic) to the alloy metal deposits.

313. Electrode Coatings

The AWS and ASTM classifications indicate the main types of coatings, but each manufacturer has his own particular compounds, and very few of the electrodes behave exactly the same.

Some of the more common coating materials are listed as follows: cellulose, potassium, alpha quartz ($Si\ O_2$), anatese and rutile ($Ti\ O_2$ or $Fe\ Ti\ O_3$), calcium fluoride ($Ca\ F_2$), calcium carbonate ($Ca\ CO_3$), sodium carbonate ($Na_2\ CO_3$), aluminum oxide ($Al_2\ O_3$), magnesium oxide ($Mg\ O$), and manganese oxide ($Mn\ O_2$).

Some of the popular electrode coatings have approximately the following compositions:

E 6010 $Ti\ O_2$ (anatese or rutile).

E 6011 $Ti\ O_2$ (anatese or rutile) and calcium carbonate.

E 6013 $Ti\ O_2$ (rutile) and quartz.

E 6020 ($F_2\ O_3$) ferric oxide and quartz.

E 7015 $Ca\ CO_3$ (calcium carbonate), ($Ca\ F_2$) calcium fluoride and $Ti\ O_2$ (rutile).

ELECTRODE COATING COMPOSITIONS AND APPLICATIONS
(Right hand digit in the American Welding Society number)

Right Hand Digit	Coating Compositions	Application (use)
0 AWS E-6010	High cellulose sodium with some titanium oxide (Ti O_2) anatese or rutile.	Forms a light slag, and forms a carbon monoxide gas which produces a reducing atmosphere around the arc. It eliminates oxidation. It is used on all mild steel applications (General welding). Use D.C. reversed polarity.
1 AWS E-6011	Same as "O" with arc stabilizer included (potassium salt)	Same as (O) above except it can be used on A.C. Use D.C. reversed polarity or A.C.
2 AWS E-6012	Coating of titania or rutile (sodium)	It has very little splatter; it is easy to handle the puddle and to fill gaps. Use D.C. straight polarity.
3 AWS E-6013	Same as "2," but coating contains an ionizing agent (potassium salt)	It is good for low voltage, low current applications. It allows a varying arc length, and makes it easy to maintain an arc. It is particularly useful with small electrodes used in connection with small capacity A.C. transformer type welders. It is particularly suitable for many farm applications and also for sheet metal work. Use D.C. straight polarity or A.C.
3 b (not an AWS Standard)	Same general composition as 3 above with an added substance to produce both a more fluid slag and puddle	Generally has the same characteristics as "3" above, with the added characteristics that it is faster. It will penetrate and fill gaps better. Since the puddle is more fiuid, the welds should be made in the horizontal position, and the beads will be low and flat. Use D.C. straight polarity or A.C.
4	As of 1951, this number is little used	
5 AWS E-6015	Low hydrogen (sodium)	This is a low hydrogen electrode for welding low carbon, alloy steels. Power shovels and other earth moving machinery require this rod. The weld machines or files easily. Use D.C. reversed polarity only.
6 AWS E-6016	Same as "5" but with potassium salts used for arc stabilizing	It has the same general application as (5) above except it can be used on either D.C. reversed polarity or A.C.
7-19 Inclusive	These numbers are not in use as of 1951	

Note that the following electrodes are considered to be chiefly for production purposes and should be used in a horizontal or near horizontal position only. The coating will withstand a high temperature. High currents (amperage) may be used.

Right Hand Digit	Coating Compositions	Application (use)
6 AWS E 60 26	High iron oxide (Low hydrogen) Flat and horizontal fillet weld position	For low carbon alloy steels, use D.C. straight polarity or A.C.
6 AWS E 60 36	High iron oxide (Low hydrogen) Flat position only	For low carbon alloy steels, use D.C. straight polarity or A.C.

314. Low Hydrogen Electrodes

Hydrogen has harmful effects on alloy steels, causing intergranular cracks, thus lowering fatigue resistance and strength.

Low hydrogen electrodes deposit a minimum of hydrogen in the weldment. The low hydrogen condition is obtained by using a special coating (XXX6). Both lime coatings and Titania coatings are

CURRENT SETTINGS FOR LOW HYDROGEN ELECTRODES

Electrode diameter	Amps. Flat	Amps. V & O	Volts
1/8	140-150	120-140	22-26
5/32	170-190	160-180	22-26
3/16	190-250	200-220	22-26
7/32	260-320		24-27
1/4	280-350		24-27
5/16	360-450		26-29

Figure 270. The arc machine settings when using ferritic (low hydrogen) electrodes in various positions

PHYSICAL PROPERTIES OF FERRITIC ELECTRODE WELDS

	As Welded	Stress Relieved
Yield	67,000-72,000 psi	65,000-70,000 psi
Tensile	79,000-85,000 psi	77,000-83,000 psi
Elongation in 2"	20-26%	24-30%
Reduction of Area	35-50%	55-68%

Figure 271. Typical properties of ferritic electrode arc welded joints

used. The electrode conforms to AWS E-6016 and E-7016 specifications and is used on hard-to-weld steels (free machining), high carbon, low alloy, and hardenable steels. The slag is very fluid, but good flat or convex beads are easily obtained.

These special coatings contain practically no organic material, and the baking cycle near 600°F during welding eliminates free moisture. These electrodes may best be used as shown in *Figure 270.*

The deposited metal has excellent tensile and ductile qualities and

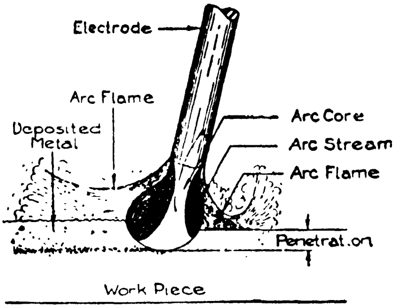
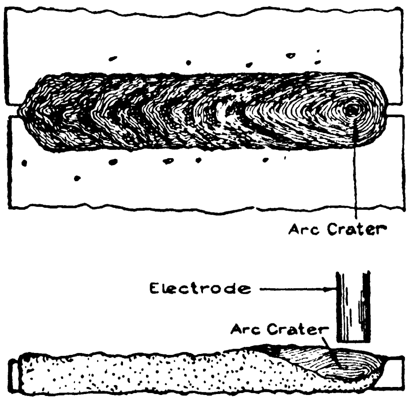


Figure 272. The basic operation of a bare electrode arc

is exceptionally clean as may be seen by X-ray inspection. *Figure 271.*

The electrode may be used with either A.C. or D.C. (straight or reversed) current. The electrodes should be baked at 250°F before using to remove moisture if they have been exposed to the atmosphere for an appreciable period. Never exceed a ½″ motion, and practice considerable care during vertical and overhead passes.



Longitudinal section of deposited metal showing penetration and arc crater

Figure 273. The weld obtained when using a bare electrode

315. Electrode Techniques (Bare and Light Coated Electrodes)

The manipulation of the electrode when arc welding is very important. One should understand that any changes of motion, angle, and arc length affect the quality of the weld. *Figures 272, 273,* and *274.* The amount of current is very important, and the values shown

in *Figure 48* should be followed. It should also be remembered that there is some difference in D.C. and A.C. arc welding due to the arc action.

In manual metal arc welding, proper fusion, penetration, and soundness of weld is best secured by using as short an arc as can be maintained for each form of weld. A typical example of proper arc length for given thickness of base metal and for a 3/8-in. fillet weld is shown in *Figure 275*. When properly manipulated, the arc will throw a steady shower of small sparks and (in the case of bare electrodes) will be accompanied by a regular, crackling, snappy sound with fractional intervals less than one-half second between

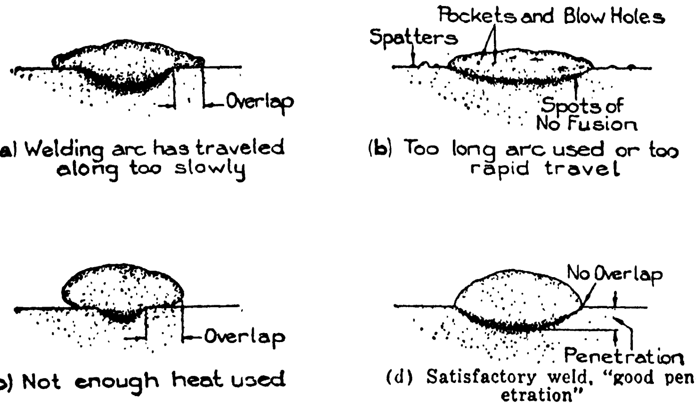


Figure 274. Good and bad weld deposits as made with bare electrodes

explosions. With a given current, the length of arc depends upon the arc voltage which should seldom exceed 20 volts.

The amount of current shall be such as will best suit the arrangement and the thickness of the base metals to be joined. It will vary with base metal thickness and size of electrode used. Sizes and current values that have been found suitable for welding are given in *Figure 276*. In special cases other approved sizes and currents may be specified. The current and voltage used shall be measured by suitable meters, either mounted on the arc welding machine panel, or portable, for use at the point of welding. Allowance shall be made for line drop where the meters are not adjacent to the point of welding.

The arc shall be started by drawing a long arc momentarily to preheat base metal before deposition of filler material to insure

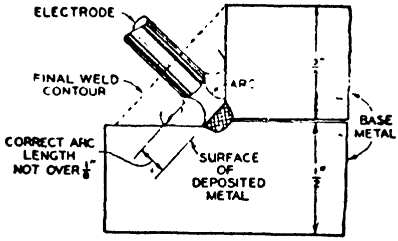


Figure 275. A bare electrode fillet weld

thorough fusion at start of weld. This may also be accomplished by moving a short arc rapidly back and forward over a limited area at the start.

In case of a long weld where more than one electrode is used, the arc shall be re-started about ¼ in. to ⅜ in. ahead of the crater, going back over the crater to properly fill it and keep a uniform contour, thus insuring proper preheating as in start of weld.

On single layer welds the arc may progress with either a straight forward motion or an oscillatory motion depending on size of joint to be filled to bring it up to proper contour and insure proper fusion in root zone.

Size of Weld, In.	Minimum Number of Layers	Electrodes and Current Values
¼	1	In all these cases use either 5/32-in. electrodes with 160-180 amps., or 3/16-in. electrodes with 180-225 amps.
⅜	1	
½	2	
⅝	2	
¾	3	

Figure 276. Current values and sizes of bare and lightly coated electrodes for various sizes of welds

In multi-layer welding the first layer shall be deposited by moving the arc in a straight forward motion to secure proper fusion in the root zone, while subsequently layers shall be deposited with an oscillatory motion to build up the weld to the proper contour. The first layer shall be made with an electrode small enough to get thorough penetration at the root zone.

Each layer shall be thoroughly cleaned by brushing or chipping to remove all excess scale and oxides before depositing succeeding layers. The surface of each layer shall be reasonably smooth and uniform in contour.

316. Electrode Techniques (Heavily Coated Electrodes)

When making welds with heavily coated electrodes, the procedure recommended by the manufacturer of the electrodes being used should be followed. However, if such instructions are not available, the following procedures should be helpful.

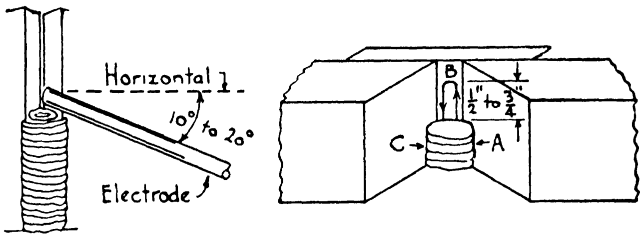


Figure 277. Vertical butt weld—first layer

The amount of current shall be such as will best suit the arrangement and the thickness of the base metal to be joined. The current and voltage used shall be measured by suitable meters, either mounted on the arc welding panel, or portable, for use at the point of welding. Allowance should be made for line drop where the meters are not adjacent to the point of welding. *Figure 48.*

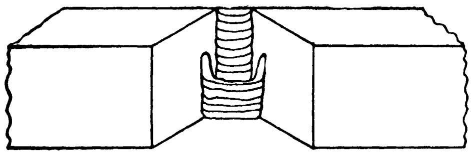


Figure 278. Vertical butt weld—second layer

In making butt welds on bevel joints, weave the electrode from one side of the joint to the other. This weaving may not be necessary on the first pass. These oscillations should be regulated so that the weld metal fuses into the side walls without directing the arc against the walls. This is accomplished by pointing the electrode downward and allowing the outer edges of the arc to play lightly on the walls. Hesitate long enough on the turns to insure complete fusion into the side walls. When flat welding with heavily coated electrodes in plate thicknesses greater than ½ in., it is sometimes desirable to bevel the plate edges in the form of a U.

The travel speed should be regulated to limit the thickness of the layer per pass to not more than ⅛ in.

One-eighth ($\frac{1}{8}$)-in. and $\frac{5}{32}$-in. diameter electrodes give best results in the vertical and overhead welding positions. However, the $\frac{3}{16}$-in. diameter is frequently used in vertical welding with satisfactory results.

Vertical welds should be made by welding upward. Referring to *Figure 277*, the first pass is started by oscillating or weaving the

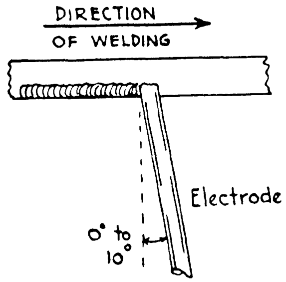


Figure 279. Overhead butt weld

electrode from side to side (A) to produce a weld metal bridge across the "V." Then the arc is moved rapidly upward for $\frac{1}{2}$ to $\frac{3}{4}$ in. along the bottom of the "V" (B), drawing a long arc (about 30 volts), and then back down to the crater again (C), shortening the arc to its previous length. The movement up and down requires about $\frac{1}{3}$ sec. and is very easily accomplished with a bending action

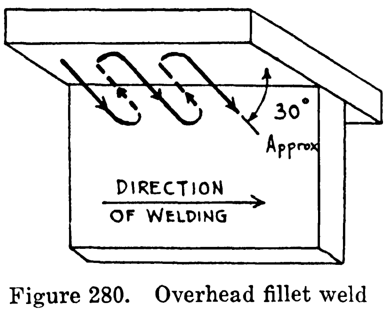


Figure 280. Overhead fillet weld

of the wrist. Its purpose is to allow the molten metal in the pool to solidify and to preheat the plates ahead of the crater. It is sometimes called a "Blip" motion.

The above cycle of operation is repeated all the way up, each time depositing a thin layer of metal on top of the preceding layer. The quantity of metal deposited on each cycle will depend upon the current, ability of plate to absorb the heat, etc. The travel speed on

the first pass should be regulated to limit the deposit to the equivalent of about ¼-in. fillet weld. On succeeding passes, the thickness should not exceed ⅛ or $\frac{5}{32}$ in. The successive passes may be made by this up and down technique or by successive horizontal weaving.

If, in making the second and succeeding passes, a procedure similar to that of the first pass is used, the motion *(Figure 278)* is across the pool or shelf, then upward and back at one side of the "V," then across the shelf to the other side, and up and back to the shelf again. The up and down motions should be done rapidly, lengthening the arc while doing so. If the procedure of weaving straight across is used, it should be similar to the above except that the up and down motion at each end of the shelf is eliminated.

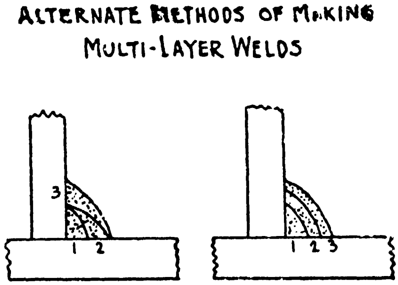


Figure 281. A multi-layer flat, vertical or overhead fillet weld cross section

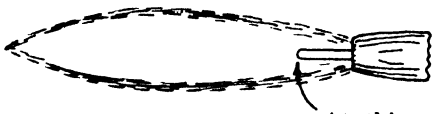
For overhead butt welds, the procedure is much the same as that previously described for vertical welds. The electrode is pointed upward and sometimes leaning slightly forward, as shown in *Figure 279.* A shelf on which to work is deposited at the start, and the cycles of operation are the same as those for vertical welding.

For light fillet welds (¼ in. or less) and the first pass of multiple pass welds, the electrode should be moved only in the direction of travel. The second and successive passes or heavy single-pass welds (⅜ in. for example) should be made by weaving the electrode in a plane making an angle of about 30° with the underside of the plate, as shown in *Figure 280.* The solid line represents actual welding. The dotted line represents an upward skip done in about ⅓ sec.

Vertical fillet welds are made in the same manner as vertical butt welds.

In many cases fillet welds in sizes up to ⅜ in. can be made in a single pass by holding the electrode at a suitable angle and moving it along at a uniform rate. The angle will vary with the size and

type of electrode and the relative thickness of the materials forming the joint. Where the fillet weld requires more than one layer, the second and subsequent layers may be deposited as a complete spread over the previously deposited metal or in two or more parts as shown in *Figure 281*. The sequence in which these various layers should be deposited may vary from case to case.



At this point in the neutral flame, a slight increase in the amount of acetylene would show up as a whitish feather.

Figure 282. A neutral oxy-acetylene flame

The welder should know the manufacturer's recommendations concerning the electrode being used. The setting of the machine must be carefully done. Those machines with remote adjustments placed near or at the place of welding are excellent aids to the welder to get accurate settings.

317. Gas Welding Techniques

There is a definite technique and art to the use of filler rods when gas welding. The proper size filler rod, the composition of the filler

FILLER ROD GUIDE

Filler Metal Dia., in.	Thickness Base Metal, in.	Tip Size	Tip Drill Size
1/16 to 3/32	1/8	3-5	54
1/8	3/8	7-11	50
5/32 and up	1/2 to 5/8	10-14	34

Figure 283. A table of filler rod sizes and tip sizes for various thicknesses of steel

rod, and the manipulation of the filler rod in relation to the torch is all important.

The size of the inner cone or inner cones must be regulated for varying thicknesses of base metal so that the proper amount of heat and flame condition is obtained to properly perform the welding operation. The criterion for welding flame regulation is that the inner cone or inner cones should be of a size and character which produce sufficient heat to maintain the welding puddle in a quiet

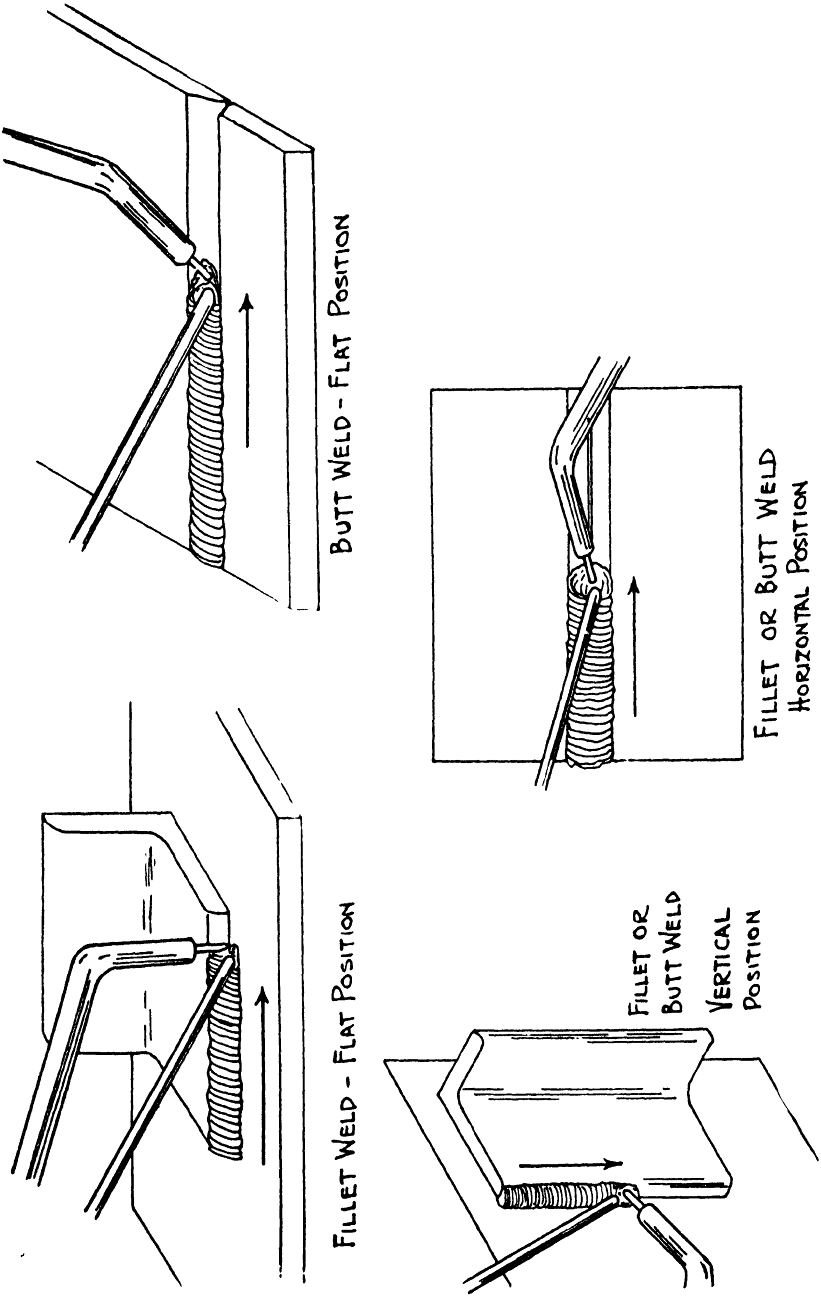


Figure 284. The positions of the rod and flame in backhand technique. The arrow indicates the direction of welding

molten state, and to cause fusion of the welding puddle with the base metal.

The orifice of the welding tip must be kept clean at all times during the welding operation so that the regular and symmetrical inner cone or cones can be maintained *(Figure 282)*.

A guide to filler rod size is shown in *Figure 283*.

It is of utmost importance that the filler rod be clean and that its sulphur content not exceed .05%. The torch *must* have that size tip and be so adjusted that the welding puddle is quiet (not being blown about by a high velocity flame), to produce good fusion with the base metal.

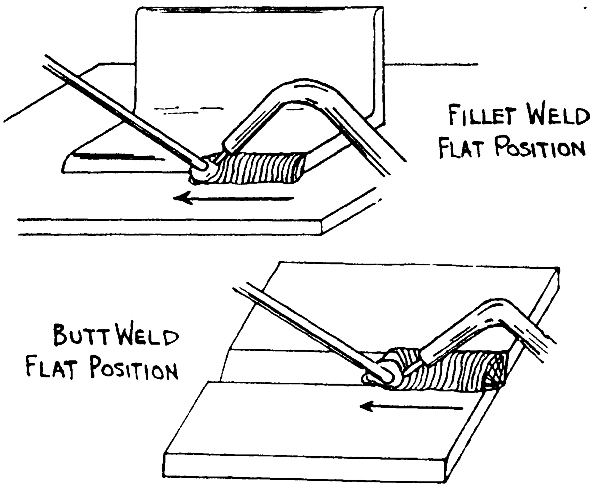


Figure 285. The positions of the rod and flame in forehand technique

In starting a weld, the base metal shall be heated to a dull red for a distance of from 1 to 2 in. along the joint so that the point of welding can be brought to the fusion temperature evenly before welding rod is added. If the weld is stopped for any reason, the same precautions should be observed upon restarting.

In making tack-welds, the same precautions should be observed as when starting welds. Where a designed weld will later be made over the tack-weld, the tack-weld must be made with the same care as required for designed welds.

The welding torch and welding rod should be manipulated to maintain a definite puddle of molten weld metal without overheating either the base metal or deposited metal. Good practice requires that the end of the welding rod be kept within the limits of the

puddle at all times, particular care being taken not to disturb the rear edge of the puddle which might cause slag on the surface to become entrapped in the weld metal. In manipulating the flame, the tip of the inner cone should preferably not touch either base metal, puddle or welding rod.

Either backhand or forehand technique may be employed. The various positions of welding rod and flame with respect to each other in backhand and forehand techniques are illustrated in *Figures 284* and *285*.

In carrying the puddle forward, the base metal surfaces just in advance of the puddle should be prepared for fusion with the puddle by melting sufficient surface metal to remove oxides and expose sound base metal. In some cases this depth of melting may be 1/32 in. or less. Manipulation of the rod and flame in controlling the puddle should be such that at no time is molten metal from the puddle permitted to flow ahead until this melting has occurred.

For welding in positions other than flat, it is permissible to carry a fairly shallow puddle for convenience in controlling it. When using backhand technique, this may be done by distributing the molten metal in the puddle with the end of the welding rod, providing the puddle is kept sufficiently molten so that surface oxides do not become entrapped in the weld.

When fillet welding in the flat position, there is a tendency for the top plate to melt before the bottom plate. This should be avoided by pointing the flame more against the lower plate as shown in *Figures 284* and *285*. It is essential that fusion be secured at the inside corner or root of the joint; the welding rod and inner cone should be manipulated so this result will be secured. If desired, the welding rod may be stirred lightly, well within the bounds of the puddle, to maintain a shallow puddle and distribute the molten metal to obtain readily welds of proper size and shape.

When butt welding in the flat position, manipulation of rod and inner cone must be such that the bottom of the vee is fused together at the same time but in advance of the upper walls of the vee so that the weight of the puddle does not cause molten metal to sag inside the joint. Where spacing of the joint exceeds 1/16 in., it is allowable to weld the bottom of the vee together in a separate operation, 1/2 in. to 1 in. at one time ahead of the principal point of welding.

Multiple layer welding may be used in place of single layer welding for all positions of welding and thicknesses of metal, but espe-

cially for welds of larger size. The usual criterion is the size of puddle that can most effectively be carried by the welder for the particular position of welding. If the completion of a weld in one layer requires a puddle larger than indicated by this criterion, two or more layers should be made.

The layers of the weld may be made continuously for the full

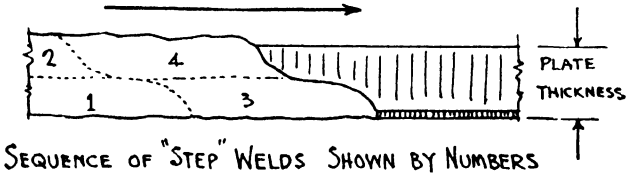


Figure 286. The "step" method of multi-layer welding

length, or the welding may be done by the "step" method illustrated in *Figure 286*.

The quality of the resultant welds can be inspected by noting the size, shape and condition of the filler metal joint. *Figures 287, 288, 289*.

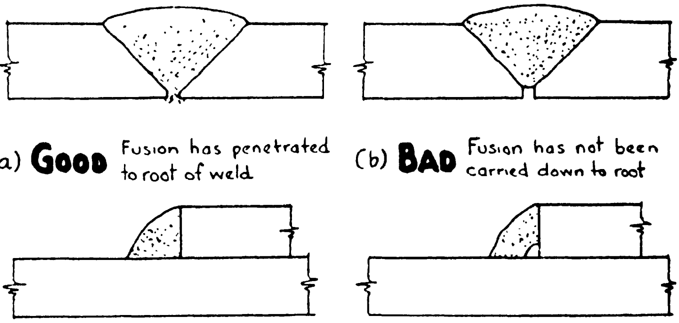


Figure 287. Examples of butt and fillet joint welds, cross-sectioned

318. Soft Soldering

Soft solders are made principally of lead and tin. There are several of these alloys available. The 38% lead, 62% tin alloy has the lowest melting temperature and melts at 361° F. This is the eutectic alloy. The commonly used alloys of these metals are listed in the table, *Figure 290*. Some soft solders have small amcunts of other metals included in the alloy to produce special properties. Such metals as silver, bismuth, and antimony are examples of these alloying metals. A new series of soft solders containing Indium are now

used where corrosion difficulties may be encountered. A typical Indium solder consists of 25% Indium, 37.5% tin, and 37.5% lead which melts at 274° F. and flows at 358° F.

319. Copper Brazing Alloys

The use of brazing alloys to join steel and cast iron parts together

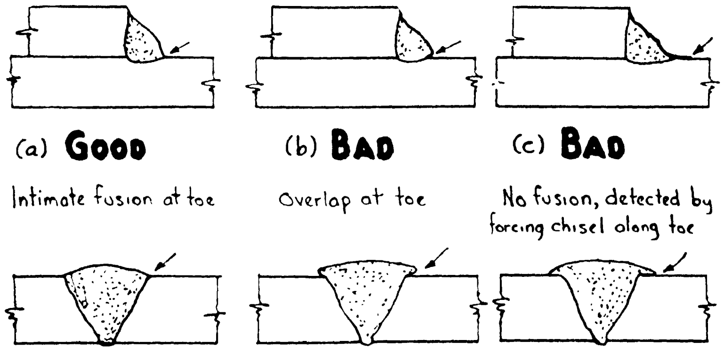


Figure 288. Types of correctly welded and poorly welded fillet and butt joints, cross-sectioned

without heating the parts to their plastic or molten condition has been in popular use for many years. The principal metal in these brazing alloys is copper with zinc and tin as the other alloying metals. These alloys melt at temperatures between 1300° F. and 2150° F.

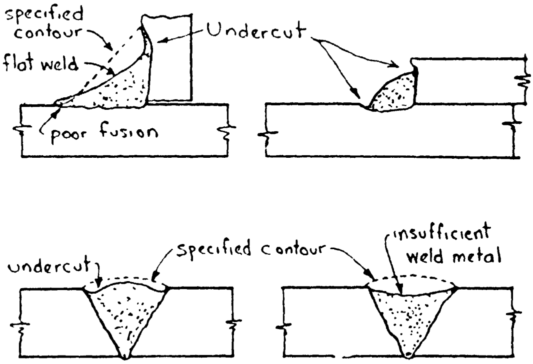


Figure 289. Examples of typical welded joint faults, cross-sectioned

Some of these alloys are listed in *Figure 291*. Also Paragraph 137.

320. Silver Brazing

Many new silver brazing alloys are on the market, and each alloy has its own particular fields of application.

These alloys vary in melting temperature and in flow temperature. The term "melting" temperature means the temperature at which the alloy starts to melt, while "flow" temperature means the temperature which the alloy must reach so that all the metal alloy is liquid. These temperatures may vary for some alloys from 1125° F. melting to 1295° F. flow.

A wide temperature difference between the melting temperature and its final higher flow temperature presents some difficulties. While applying one of these latter alloys, the lower melting temperature parts (constituents) may flow into the cracks and leave the higher temperature parts of the alloy behind. This action causes a change in color and strength, and it also causes difficulty in flowing in the alloy. It is best therefore to heat the alloy quickly, first to minimize oxidation and second to prevent alloy separation. The separation

LEAD-TIN SOLDERING ALLOYS

Lead %	Tin %	Melting Temperature °F	Flow Temperature °F	Use
38	62	361	361	
40	60	361	370	General
50	50	361	420	General
60	40	361	460	General
70	30	361	500	General
95	5	570	595	High Temperature Solder

Figure 290. A table of the melting temperatures of lead tin soldering alloys

feature of the wide temperature range alloys is an advantage in poor fit-ups and in fillets, as the higher temperature alloys parts will bridge better. *Figure 292.*

Cadmium and zinc are used as alloying metals in silver brazing alloys because they have the peculiar ability to "wet" or flow and alloy with iron. They also lower the alloy melting and flowing temperature. *Figure 293.*

There is some danger of producing harmful fumes from the zinc and cadmium if alloys containing these metals are violently overheated and the metals vaporize. The premises should be well ventilated if there is any possibility of overheating.

Silver brazed joints are very strong if properly made. In joining stainless steel using butt joints, silver brazed, the tensile strength varies as shown in *Figure 294.*

One of the best methods to connect parts in a leak proof manner and to provide maximum strength is also to silver braze the joint. These joints are very strong and will stand up under the most extreme temperature conditions and vibrations. *Figure 295.* Silver

POPULAR COPPER BRAZING ALLOYS

	Copper %	Zinc %	Tin %	Fe %	Mn %	Si %	Ni %	P %	Use	Trade Name	Melting Temp °F	Flow Temp °F
Brass Brazing Alloy	60	40							Copper Nickel Alloy Steel	All State 41	1650	1660
Naval Brass	60	39.25	.75						Copper Steel Nickel Alloys		1630	1650
Tobin Bronze	59	40.5	.50						Steel Cast Iron	Anaconda 481	1625	
Manganese Bronze	58.5	39.25	1.0	1.0	.25				Steel	Oxweld #10 Anaconda 984	1590	1630
Low Fuming Bronze	57.5	40.48	.9	1.0	.03	.09			Cast Iron Steel	Anaconda 997	1598	
	52. 50	48. 50.									1570 1585	1595 1610
Nickel Silver	55-65	27-17					18		Steel Nickel Alloys Cast Iron	Anaconda 828		
	48	42					10		Steel Nickel Alloys		1690	1715
Copper Silicon	98.25				.25	1.5			Steel to Copper	Anaconda 943	1981	
Phosphor Bronze	98.2		1.5					.3	Copper Alloys	Anaconda 903 All-State 21	1922	

Figure 291. A table of popular copper brazing alloys. Note that all of these alloys melt at a lower temperature than the melting temperature of copper. (1980° F)

Figure 292. An assembly of steel parts joined by a 45% silver alloy. Note the neat fillets at the edge of the spuds
(Courtesy of: Handy & Harman)

SILVER BRAZING ALLOYS

ASTM Spec #B-73-29	Silver	Cu	Percent Zinc	Cadmium	Melts °F	Flows °F	Color
	9	53	38		1450	1565	
1	10	52		.05	1510	1600	Yellow
	*15	80		(5% Phos)	1185	1300	Gray
2	20	45	35	.05	1430	1500	Yellow
3	20	45	30	.05	1430	1500	Yellow
	30	38	32		1370	1410	
	**35	26	21	18	1125	1295	Almost white
	40				1135	1205	Almost white
4	45	30	25		1250	1370	Almost white
	**45	15	16	24	1125	1145	Almost white
5	50	34	16		1280	1425	Almost white
	**50	15.5	16.5	18	1160	1175	Almost white
	**50	15.5	15.5	16 (3% Ni)	1195	1270	White
6	65	20	15		1280	1325	White
7	70	20	10		1335	1390	White
8	80	16	4		1360	1490	White

***—A special alloy containing phosphorous and used only on non-ferrous metals.**
****—Some special alloys of silver using a cadmium content.**

Figure 293. A table of silver brazing alloys

soldering, or silver brazing as it is more correctly called, can be easily done if the correct procedure is followed. The points to be remembered are as follows:

a. Clean the joints mechanically.
b. Fit the joint closely and support the joint.
c. Apply the proper flux.
d. Heat to the correct temperature.

STRENGTH OF SILVER BRAZED BUTT JOINT

Thickness of alloy in joint in inches	Tensile Strength lbs. per sq. in.
.002	133,000
.003	115,000
.006	90,000
.009	83,000
.012	76,000
.015 app. 1/64	70,000

Figure 294. Strength obtainable with silver brazed butt joints. Note that a thin layer of braze metal is stronger than a thicker layer

e. Apply the silver solder.
f. Cool the joint.
g. Clean the joint thoroughly.

An oxyacetylene torch is an excellent heat source for silver brazing although any bottled fuel in conjunction with oxygen is acceptable. *Figure 296*. There are various silver alloys on the market.

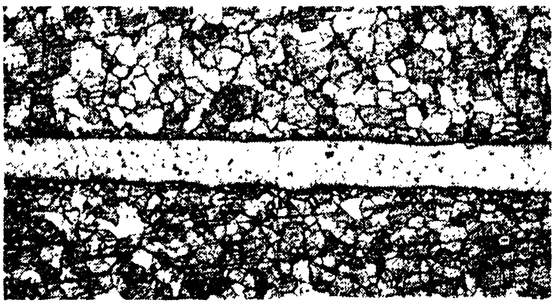


Figure 295. A microphotograph of steel parts brazed together using a 45% silver alloy. 200x
(Courtesy of: Handy & Harman)

Those having a 35% to 45% silver content are becoming increasingly popular. The parts to be soldered or brazed must be made to fit accurately and must be thoroughly cleaned. Any external surface should be cleaned with steel wool to remove dirt. Other types of cleaners may leave abrasives or an oil film. Internal circular

surfaces can be cleaned with clean wire brushes, with steel wool rolled on a rod, or by using a clean drill.

The parts must have contacting surfaces of sufficient size, such as a tubing sliding into a fitting (not a drive fit) to get a strong fit. The contacting surfaces need not be very large, usually three times the thickness of the thinnest piece of metal in the joint. If the parts are dented or are out of round, this fault must be corrected before the brazing is done. It is important to support the parts securely during the operation as no movement should take place while the alloy is flowing and solidifying.

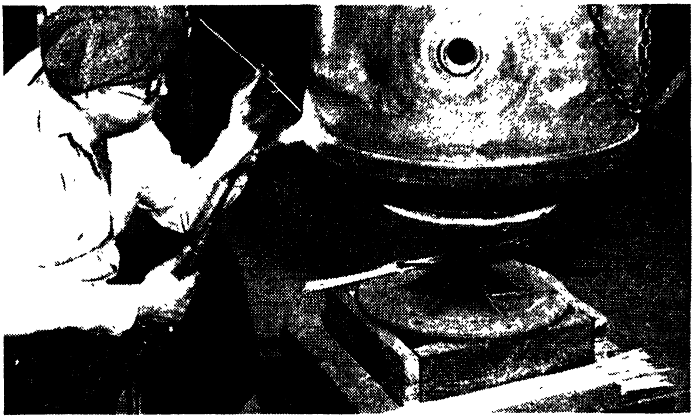


Figure 296. A water tank joint (copper) being silver brazed. Note the large torch tip, the absence of flux and the clean fillet
(Courtesy of: Handy & Harman)

The heating of the joint must be very carefully done. Watching the flux behavior is the best way to learn what the temperature of the joint is as the heating progresses. Keep the joint covered with the flame during the whole operation to prevent air getting to the joint. A large tip is recommended for heating the joint, as the extra heat permits a shorter brazing time, thus reducing the time for oxides to form. The flame should not blow either the flux or the molten metal. Use a slight feather (reducing flame) on the inner cone for best results.

The flux first will dry out as the moisture (water) boils off at 212° F. Then the flux will turn milky in color and will start to bubble at about 600° F. Finally it will turn into a clear liquid at about 1100° F. This last temperature is just short of the brazing temperature, and this clear appearance of the flux will indicate the time

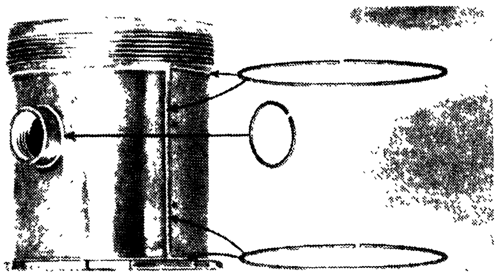


Figure 297. A silver brazed joint. This job uses three preplaced rings. Note that the alloy moved completely up and down the vertical seam from metal supplied by the two large rings. The alloy forms almost perfect fillets and no further finishing is necessary. A 45% silver alloy was used and the metal parts are made of 18-8 stainless steel
(Courtesy of: Handy & Harman)

to start adding the filler metal. The 45% alloy melts at 1120° F. and flows at 1140° F.

A torch tip of several sizes larger than the tip used for welding should be used. It is necessary to heat *both* pieces which are to have

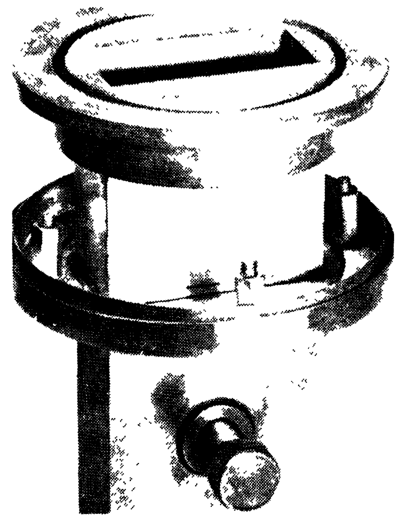


Figure 298. A radar plumbing assembly made of brass and copper parts. A 15% silver plus copper and phosphorus alloy was used to join the parts. Note the cleanliness of the joints and the even fillets
(Courtesy of: Handy & Harman)

the silver alloy adhere to them. Keep the torch in motion while the alloy is being added or local "hot" spots will result in a poor joint.

A popular way to apply silver solder when making a silver braze on a tubing joint is to use silver alloy rings. This method is prob-

ably the best way to add silver solder and is the most economical when used on a production basis. *Figure 297.*

It is necessary to thoroughly wash and scrub the completed silver brazed joint. Use water. Any flux left on the metals will tend to corrode them and also hinder any painting or plating operations.

The joint may be cooled quickly or slowly. Cooling with water is permissible. This water may be used to wash the joint at the same time.

Visual inspection of the joint will quickly reveal any places where the solder did not adhere. But it is best to watch for this adherence and make any corrections during the brazing operation.

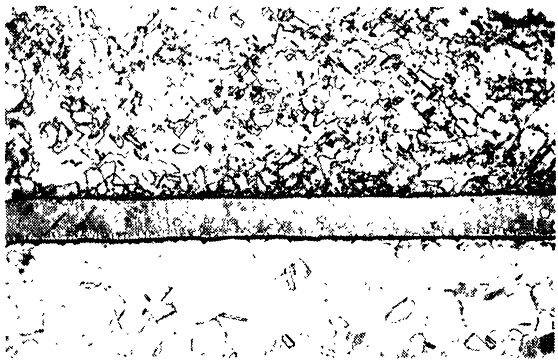


Figure 299. A microphotograph of a copper and brass part joined by a 15% silver plus copper and phosphorus brazing alloy. 200x. The top material is brass and the bottom material is copper
(Courtesy of: Handy & Harman)

When joining copper, brass, and bronze parts, a copper, silver, and phosphorous alloy may be used. This alloy has the advantage of not requiring the use of a flux. Also it's less expensive than silver solder. This alloy is not used on steel or iron alloys. No flux is necessary on copper, but brass (copper-zinc) is usually brazed with a flux. Approximately 15% silver content is standard and the alloy flows at 1300° F. *Figure 298.* The absence of flux when brazing copper improves the visibility during the brazing operation. *Figure 299.*

321. Flux and Fluxing

The use of chemicals to remove oxides and other corrosion from metals during soldering, brazing, and welding has proven very successful. These chemicals, called fluxes, produce a chemically clean surface if properly used. Some also add alloying elements while

others actually increase the fluidity or reduce the surface tension to promote more rapid flow of the metal. These fluxes are available in powder form, liquid form, paste form, and solid form (electrodes).

A method of applying flux has been developed where the flux is fed to the operation in the gaseous state. The fuel gas is fed through the container of liquid flux, and a controlled amount of the flux evaporates and is fed to the operation through the torch tip. This method

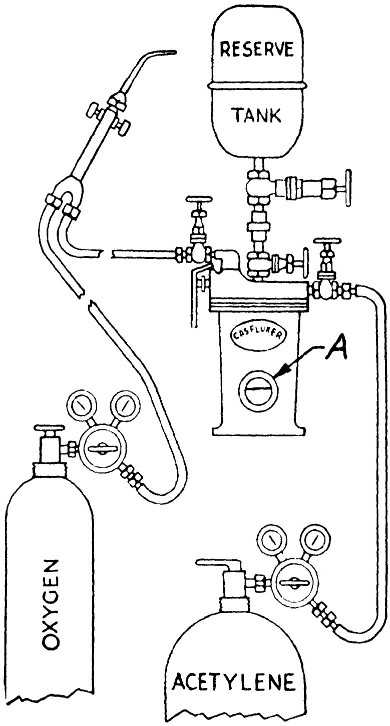


Figure 300. Liquid flux feeder installed in an oxygen-acetylene station. (A) indicates the liquid flux level
(Courtesy of: The Gas Flux Company)

eliminates the separate operation of adding flux, assures a continuous flow of flux of the correct amount, and results in an excellent and clean joint.

The method makes faster and cleaner joints possible. It minimizes after cleaning and is an excellent production device as well as being available for other applications. *Figure 300.*

Fluxes have two purposes. First, the flux excludes the atmosphere (mainly oxygen) from the molten metal. Second, the flux dissolves any oxides that may form due to some air contacting the

molten or hot metal. It is of vital importance not to blow or vaporize the flux away before it can perform its job. A large soft flame, which will quickly heat the joint (more time means more oxides) and will not blow excessively, is the best. Powder fluxes may be mixed with water or alcohol to form a more applicable paste. Clear shellac mixed with flux is an excellent way to keep the flux at the joint and on the adjoining surfaces, even under severe conditions.

Be sure the main flux container is sealed at all times to keep the flux clean. Remove only the quantity needed for the particular job.

Figure 301. Special paste solder. These compounds contain powdered metal and a flux
(Courtesy of: Fusion Engineering)

Apply the flux with *clean* brushes or paddles. These brushes and paddles should be thoroughly washed each day.

To properly proportion the flux to the joint to be brazed or soldered and to insure a correct distribution of the filler metal all along the joint, a paste made of the flux and the filler metal in a powder form is now available. This paste, *Figure 301*, is obtainable for various solders and brazing materials. It is easily applied by using special dispenser bottles, *Figure 302*.

322. Aluminum Brazing

Some aluminum alloys may be very successfully brazed. The joining metal (filler metal) is also an aluminum alloy (high silicon usually) that melts at a lower temperature than the parent metal. The brazing is usually confined to 2S and 3S (has some manganese)

Figure 302. Paste solder and dispenser
(Courtesy of: Fusion Engineering)

aluminum (non-heat treatable or "soft" alloys) and to 53S and 61S (Alcoa) and R353 and R361 (Reynolds) (aluminum, magnesium, and silicon alloys) heat treatable alloys. The brazing anneals the parts adjacent the joint. To successfully torch braze (app. 1050° F. to 1120° F.), the following steps are exceedingly important:

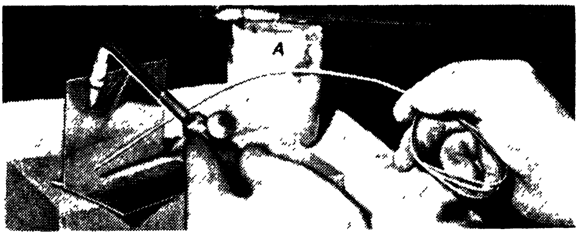


Figure 303. Torch brazing aluminum. A. Note the flux jar and brush. The position of the torch and the filler rod is important. Both the filler rod and the metal plates are prefluxed
(Courtesy of: Aluminum Company of America)

a. Clean and degrease the surface.
b. Apply a fresh, chemically clean flux, specially compounded for aluminum brazing, along the joint and on the filler rod (either in the powder or paste form). *Figure 303.*
c. Heat the joint; and as the flux chemicals turn liquid, start to apply the brazing rod. The rod will melt and flow along the joint and through the crevices by capillary action and produce a very neat fillet. *Figure 304.* Hold the torch so that the inner flame cone is one to two inches away from the same.

d. Clean the flux from the brazed joint. First use hot water, then a concentrated nitric acid solution for a few minutes, then wash again in boiling water. Any flux left on the metal will seriously corrode it.

323. Aluminum Soldering

Most aluminum alloys may be successfully soldered. The joint will be tight, but it will not have the strength of welds or brazed joints. The soldering alloy melts at approximately 400° F. and

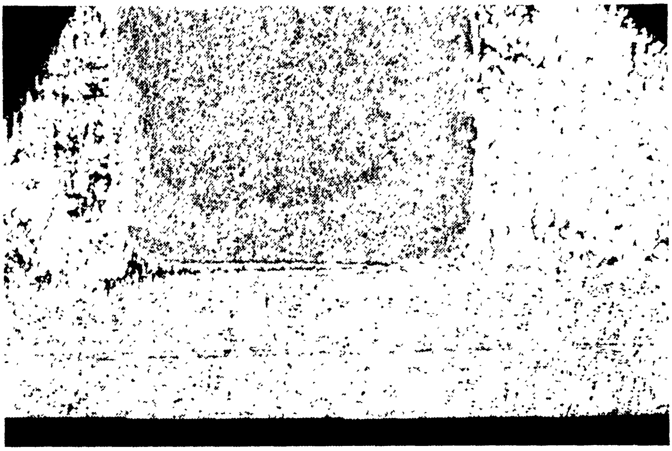


Figure 304. A 15x macrostructure of an aluminum brazed fillet joint. Note that little or no parent metal has melted
(Courtesy of: Aluminum Company of America)

flows at 450° F. The big advantage of this solder is the elimination of preheating.

Several different alloys are on the market. The manufacturer's directions for each should be followed exactly.

Usually, the joint is heated with a carburizing flame by using a large movement, and the rod (solder) is melted *only* by the heat from the metal to be joined. The joint is built to the desired fillet or build-up by rubbing the rod on the heated surface. Flux is not usually necessary, but a good aluminum flux improves the filler metal flow.

The joint must be cleaned before and after to remove dirt and grease.

The joint corrodes very readily; and if there is any chance of exposure to moisture causing galvanic action, the joint must be painted or varnished.

The aluminum solder rod is available in 1/8 in. and 3/4 in. diameters.

324. Powder and Flux Cutting

The cutting of high alloy steels and cast iron has been a difficult process until the recent development of the powder and flux cutting

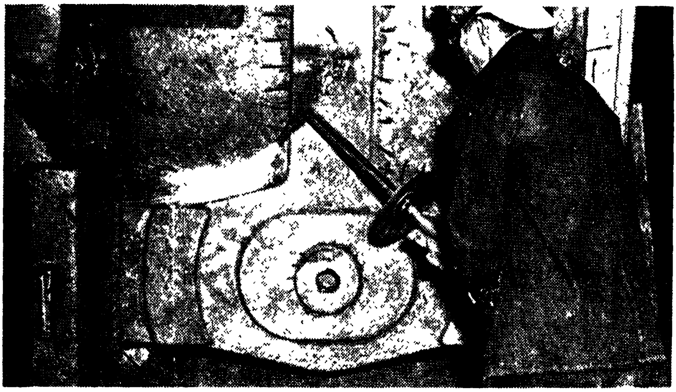


Figure 305. A powder cutting torch trimming a large casting. Note the heat shield on the torch
(Courtesy of: Linde Air Products Company)

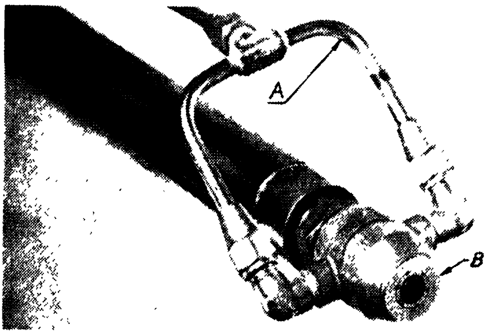


Figure 306. The nozzle end of a powder-type cutting torch. The U-shaped extra tubes (A) carry the powder. This tip design (B) permits adapting a regular cutting torch to powder cutting
(Courtesy of: Linde Air Products Company)

methods. The older methods of cutting did not work successfully because the alloy oxides melted at a higher temperature than the metal. Basically, the powder and flux cutting methods involve the use of high-in-iron powder or a flux to help remove the oxides of the alloy metals. *Figure 305* shows a powder cutting torch being used to clean a casting.

The powder cutting method provides powder fed under pressure

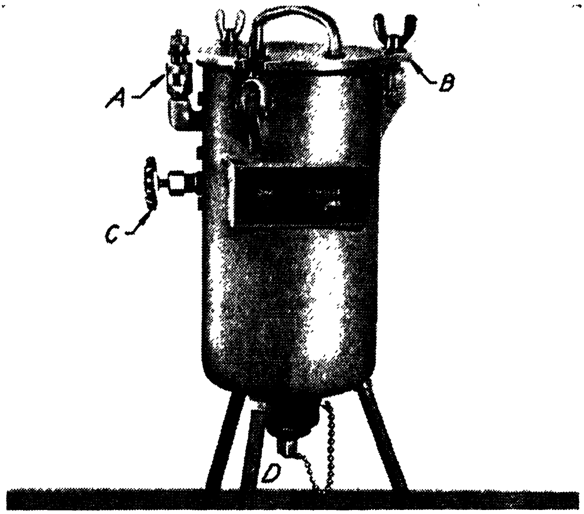


Figure 307. A powder dispenser for powder cutting: A. Air pressure release (25 lbs. per sq. in. max), B. filler cap, C. air-in valve, D. flux-out connection
(Courtesy of: Linde Air Products Company)

to the cutting torch. At the torch tip the high-in-iron particles oxidize or burn in the oxygen stream producing a very high temperature and concentrated heat, a reducing action on the metal, and a high velocity gouging action, *Figure 306.*

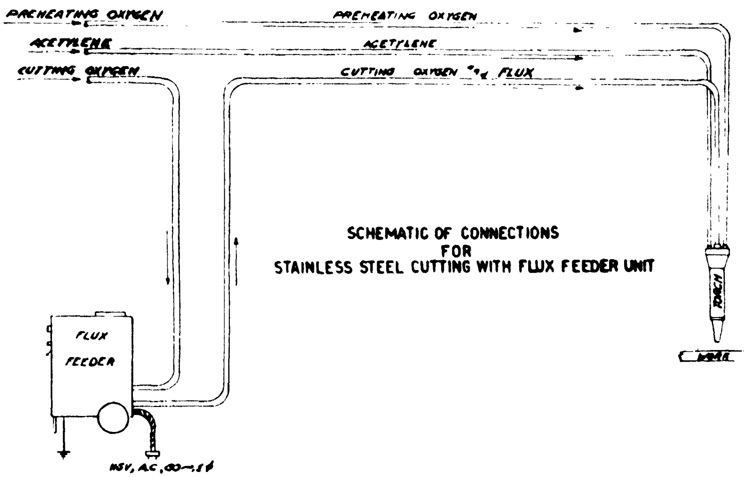


Figure 308. A schematic drawing of a flux cutting station. This method is used for many metals formerly found very difficult to cut
(Courtesy of: Air Reduction Sales Company)

This cutting method works very well on stainless steel, cast iron, high alloy steels and monel. *Figure 307.*

The extremely high temperature that results from the ignition of the powder practically eliminates the need of preheating the metal prior to the cutting action, and much time is saved. The torch also has a considerable penetrating action or carry over; therefore the cutting easily jumps slag pockets and carries over from one plate to another. The carry-over of the flux action enables cutting multiple layers of plates without clamping them together. The flux cutting method has a flux fed into the oxygen stream which causes a reducing action on the alloy oxides, permitting their easy removal from the kerf, *Figure 308.*

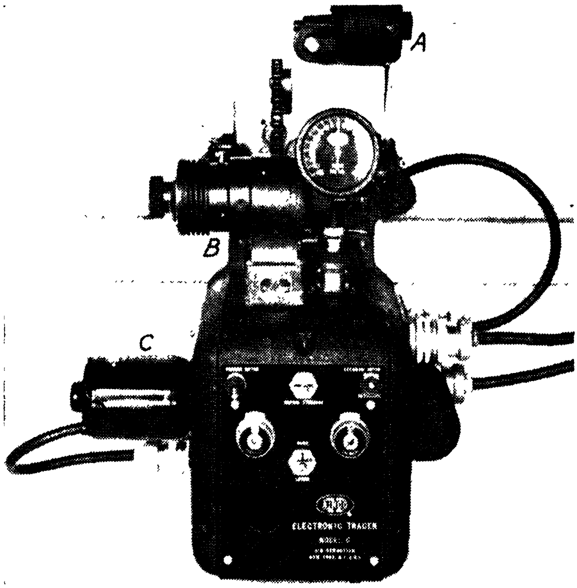


Figure 309. An electronic tracer for an automatic cutting torch. It is equipped with three motors: A. regulates the height of the unit from the drawing, B. regulates the feed (inches per minute), C. is the steering motor which keeps the apparatus on the line

(Courtesy of: Air Reduction Sales Company)

325. Automatic Cutting

Automatic cutting machines have been constantly improved. In addition to the powder and flux methods of cutting stainless steels, low alloy steels, cast iron, etc., the cutting machines have been improved by the use of electric solenoid valves to control gas flow and electronic devices for controlling the torch movement. The elec-

tronic tracers enable extremely accurate following of a template, and consequently the torch will produce almost perfect duplicate shapes. *Figure 309.* A light beam is focused downward from underneath the apparatus. A photo-electric cell picks up the light reflected upward from the line. Adjustments are made so that once the machine is set to trace a line the machine automatically follows this line with astounding accuracy. *Figure 310.* Electronic devices have also been developed to maintain a constant tip height over the metal being cut. This latter device helps insure good quality cuts at all times.

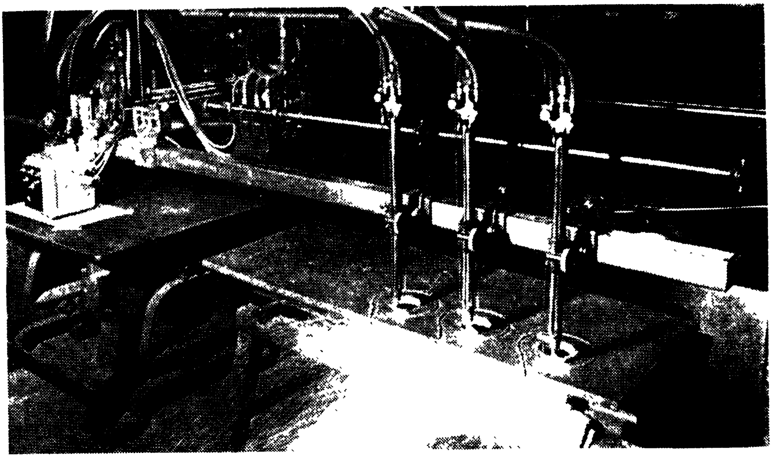


Figure 310. The electronic tracer in use
(Courtesy of: Air Reduction Sales Company)

326. Arc-Oxygen Cutting

Another method recently developed that has good cutting characteristics on difficult-to-cut metals is the arc-oxygen cutting technique. In principle, the process uses a hollow electrode. Oxygen is fed through the electrode and cuts the metal as soon as the arc is struck. *Figure 311.*

327. Underwater Cutting

Considerable improvement has taken place in the field of cutting under water. Salvage operations at Pearl Harbor, and other salvage operations during World War II provided the impetus for a great change in cutting equipment and techniques.

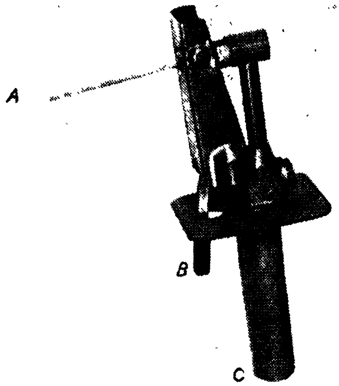


Figure 311. An arc oxygen cutting electrode and holder: A. Special hollow electrode, B. oxygen valve lever, C. cable and oxygen hose connection
(Courtesy of: Arcos Corporation)

Underwater cutting may be performed by either the gas process or electric arc process.

328. Underwater Gas Cutting

The gas torches are usually constructed as compactly as possible. The compressed air sheathing around the tip is adjustable to enable the operator to hold the torch head against the metal being cut.

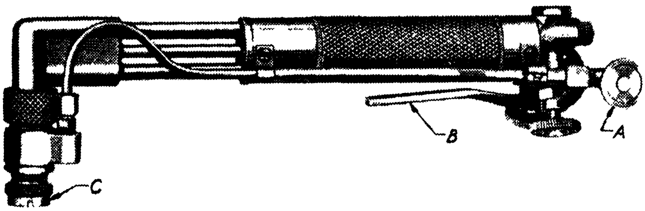


Figure 312. Underwater cutting torch: A. air control valve, B. cutting oxygen control valve, C. metal cap surrounding the cutting tip. Note the slot which allows the air and combustion gases to escape
(Courtesy of: The Harris Calorific Company)

Slots in the sheathing permit escape of the products of combustion and air. Acetylene is usually used as the fuel gas to a depth of 25 feet. Hydrogen is the fuel gas used for greater depths, see *Paragraph 200.* The tip must have exceptional preheating capacity to overcome excessive heat conductivity, corrosion, and to save the operator's time since he cannot remain at great depth except for short intervals. The air pressure and amount of air are controlled by a separate valve fastened to the cutting torch. *Figure 312.*

329. Underwater Arc Cutting

Arc-oxygen cutting underwater has proven very successful and is widely used in industry. The electrode is usually $5/16''$ tubular steel, flux-coated, and waterproofed. A special electrode holder fully insulated, without taping, is almost universally used. See *Figure 313*. This system works very well because the moment the arc is struck a very high temperature spot is produced in the metal, and the cutting will start instantly. The operator then merely draws the cutting electrode along the line of cut without holding an arc. This method of cutting is usable at all depths. All metals may be cut with this system including alloy steels, stainless, cast iron, and

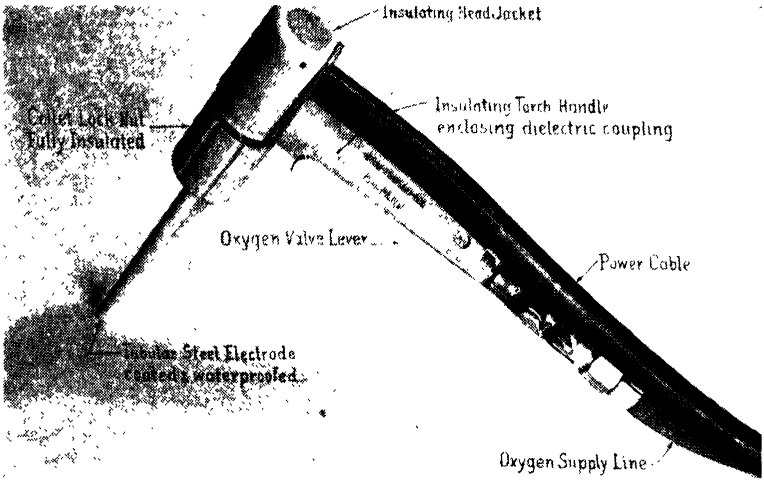


Figure 313. Underwater cutting electrode holder
(Courtesy of: Craftsweld Equipment Corporation)

all the non-ferrous metals.

Direct current, straight polarity (electrode negative) is the general practice.

330. Underwater Arc Welding

Underwater arc welding has been in use since about 1942; it is now used primarily on mild steel. Coated electrodes are used; an AWS E6013 electrode has proven to be one of the most successful. The electrode coating is especially treated with a water-proof covering (usually cellulose acetate) and then thoroughly dried. A higher amperage setting is usually used than for welding in air; approximately 10% more. Straight polarity D.C. current is used, and a

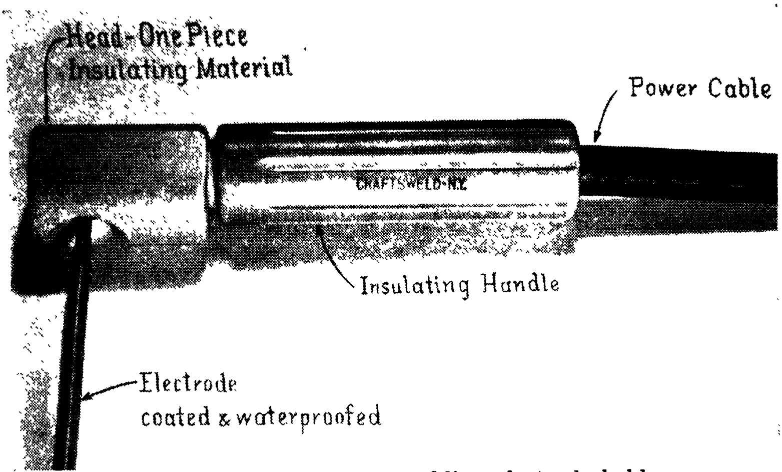


Figure 314. Underwater welding electrode holder
(Courtesy of: Craftsweld Equipment Corporation)

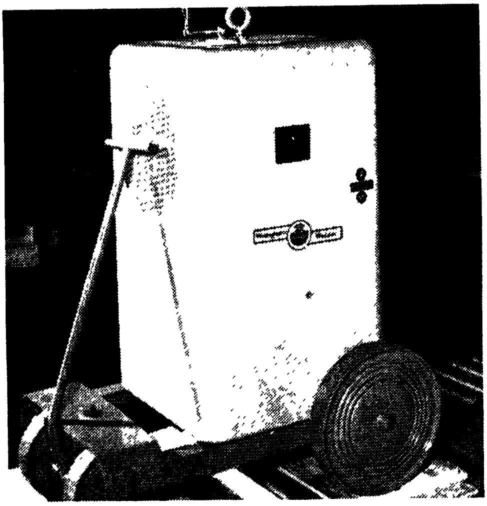


Figure 315. A direct current arc welder using selenium rectifiers. Note the adjusting handle on top, the cooling fan air outlet on the left, and the wheels for portability
(Courtesy of: Westinghouse Electric and Manufacturing Co.)

close arc is maintained. It is best to hold the electrode steady without weaving, using fillet joints in the flat position. Due to poor visibility underwater, a #4 to #8 lens is generally required.

All the electrical cable and the other parts of the welding equipment being submerged are carefully insulated and waterproofed. *Figure 314.* The diver must wear rubber mittens and a full length

diver's dress. It is recommended that a telephone communication system be used and that the arc welding current be turned on above water only under the diver's order when he is actually welding.

Fillet welds are recommended and when properly made will usually develop approximately 80% of the tensile strength and 50% of the ductility of welds made above water. One should take extensive training before attempting underwater arc welding.

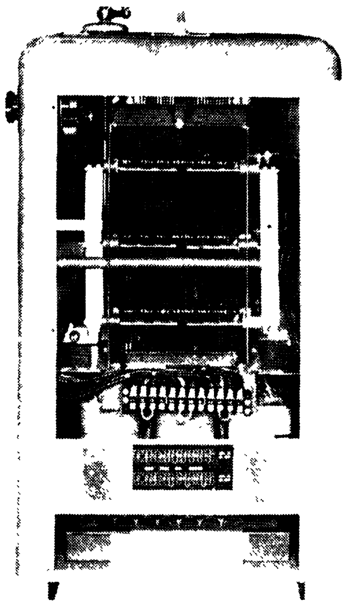


Figure 316. The internal construction of the plate type rectifier D.C. arc welder. The selenium plates are in the center. The transformer is below the plates. The air filter is at the bottom. The fine adjustment is on the left side near the top

(Courtesy of: Westinghouse Electric and Manufacturing Co.)

331. Rectifier D.C. Arc Welder

Several different developments have appeared on the welding machine market in the past several years.

The Westinghouse selenium arc welder is a D.C. welder without moving parts. It is similar in appearance to the A.C. welding machines but delivers either straight or reversed polarity direct current. It is very quiet in operation, and maintenance is reduced to a minimum, *Figure 315*. The machines are built in 200-ampere, 300-ampere, and 400-ampere capacities. The power source is three phase alternating current, and it has a three phase, full-wave se-

lenium (plate-type) rectifier. It is reported to have a high operating efficiency and a low no-load power consumption. *Figure 316. Figure 317* illustrates the wiring diagram of the selenium rectifier arc welder.

332. Dual Purpose Arc Welding Equipment

The welding generator is basically a source of electrical energy. Several of the welding companies now have available dual units that

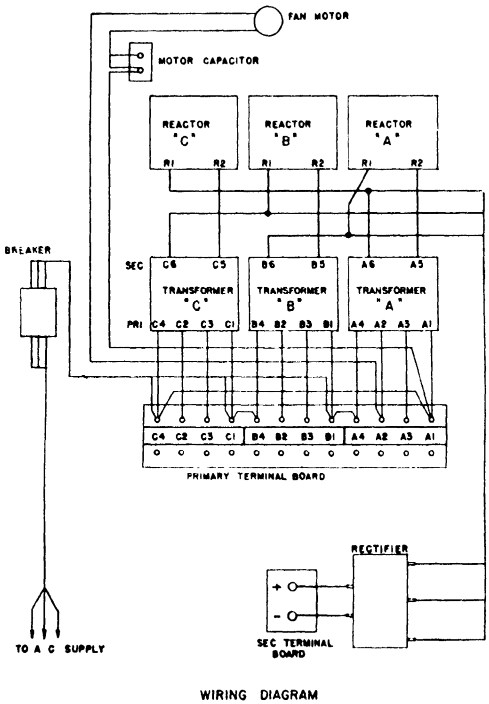


Figure 317. Wiring diagram of the selenium rectifier type arc welder. The reactors A, B, or C are the selenium rectifying elements
(Courtesy of: Westinghouse Electric and Manufacturing Co.)

are usable both as a welding machine and as a source of electric power. Many farmers, construction companies, remotely located activities, and concerns that find it wise to have stand-by electrical service use these machines. Using the machines as welders eliminates idle stand-by equipment, leaving the equipment still available for emergencies.

The machine fundamentally is an internal combustion engine-driven generator. *Figure 318.* This machine is powered by an

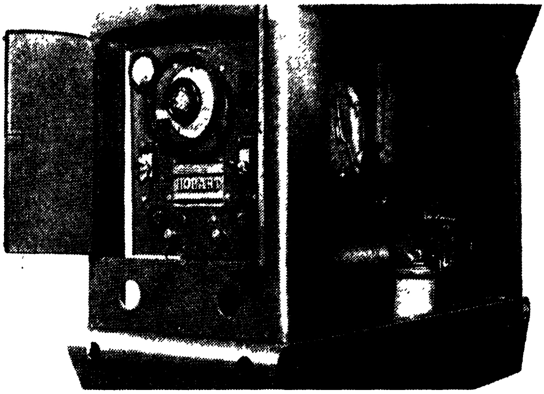


Figure 318. A gasoline engine driven D.C. welder and A.C. power source combination. This apparatus, in addition to being a welder, can furnish emergency power for construction work, etc.
(Courtesy of: Hobart Brothers Company)

automatically governed gasoline engine. These units usually operate at 1800 R.P.M. The generator can furnish up to 200 and 300 amperes (A.C.) for welding and from 5 to 8 KW at 110 volts single phase. Units of both smaller and larger capacity are obtainable. This type is the more simple of the dual-purpose units as it uses

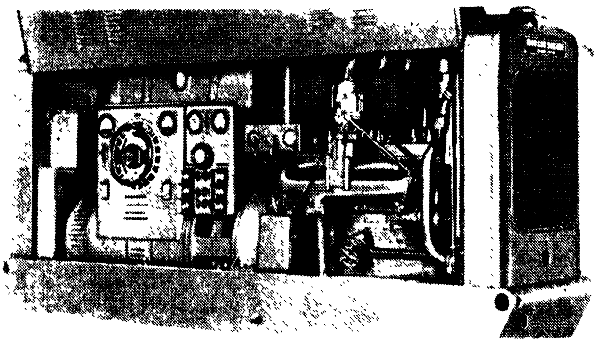


Figure 319. A D.C. arc welder and an A.C. power combination. It is used by contractors and it is also an excellent emergency stand-by unit. It is driven by a gasoline engine and can furnish both 110 A.C. and 220 A.C. three-phase power. The middle instrument panel has a frequency meter and a voltmeter.
(Courtesy of: Hobart Brothers Company)

only one generator.

Some of the larger units require up to 70 H.P. at 1800 R.P.M. and can provide either single or three phase 110 volt or 220 volt current up to 25 KW (kilowatts) (25000 watts) *Figure 319.* These units furnish up to 600 amperes D.C. at 40 volts for welding purposes. To

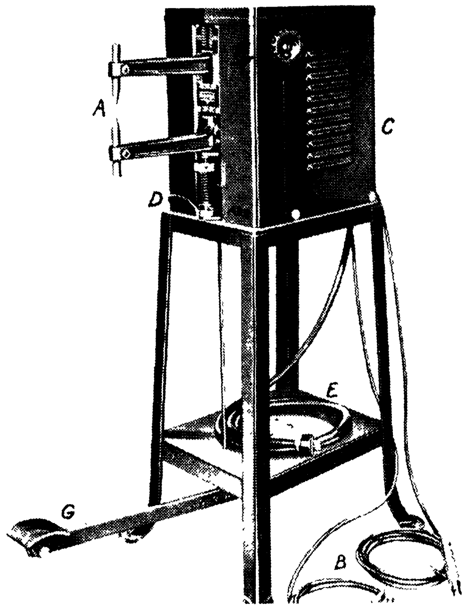


Figure 320. A combination spot welder and A.C. arc welder: A. Spot welder electrodes, B. Arc welding cables, C. Transformer housing, D. Change-over handle, E. Power cable, F. Current adjustment, G. Treadle
(Courtesy of: Delta Manufacturing Division, Rockwell Manufacturing Company)

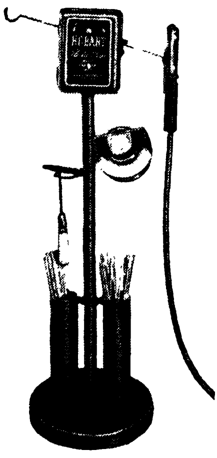


Figure 321. The Hobart Remote Start-Stop switch for D.C. arc welders. The electrode holder arm is also the switch arm
(Courtesy of: Hobart Brothers Company)

furnish both D.C. and A.C., the generator unit consists of two separate generators, one to create welding current (D.C.), the other to produce auxiliary power current (A.C.). The machine can be used both as a welder and as a power source at the same time.

In the past the usual procedure in joining sheet metal parts has been to drill holes and either rivet or use machine screws to fasten the parts together. The simplest method to join sheet metal parts

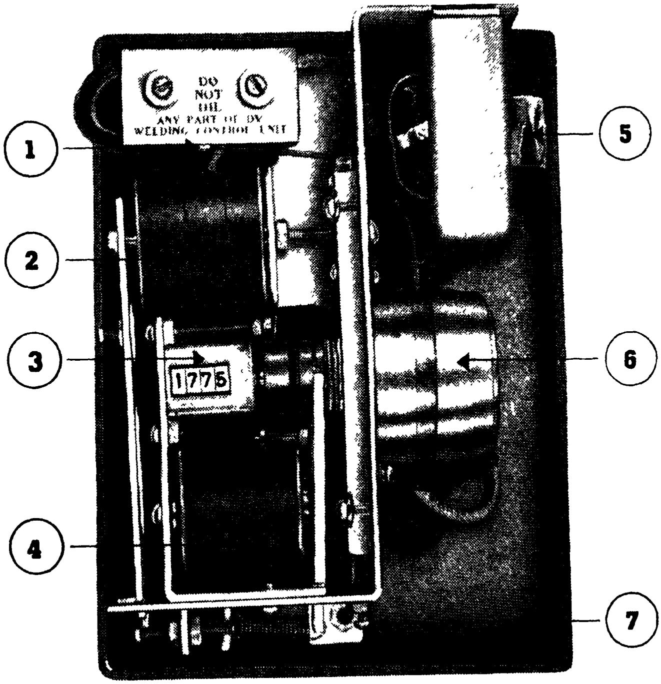


Figure 322. The D-V Automatic Start-Stop switch for D.C. arc welders, 1. Stop switch, 2. D.C. magnet coil, 3. Arc-time register, 4. A.C. magnet coil, 5. transformer, 6. motor, 7. time adjustment
(Courtesy of: DV Welding Controls)

is to spot weld them using a resistance welder. A simple machine suitable for both resistance welding and arc welding is useful for many applications. *Figure 320* shows such a machine. The spot welder tips are shown at (A). The arc welder cables (B) are connected to the rear of the transformer unit (C). A manual switch (D) is used to change the machine from a spot welder to an arc welder.

The machine shown has a 120 ampere arc welding capacity and a K.V.A. spot welding capacity. The input (Primary) is 220 volt, 60

cycle, single phase A.C. The welding current for both resistance welding or arc welding is adjusted using the control at (F). The foot treadle (G) operates the machine as a spot welder.

333. Arc Welder Remote Controls

The Hobart Electro-Mizer is a new type of remote Start-Stop switch mounted on a stand. The stand also is used to hold the remote adjustable current control, electrodes, and tools. Note that the electrode holder is hung on the Start-Stop switch arms. When the holder is removed from the arm, the machine starts; and when

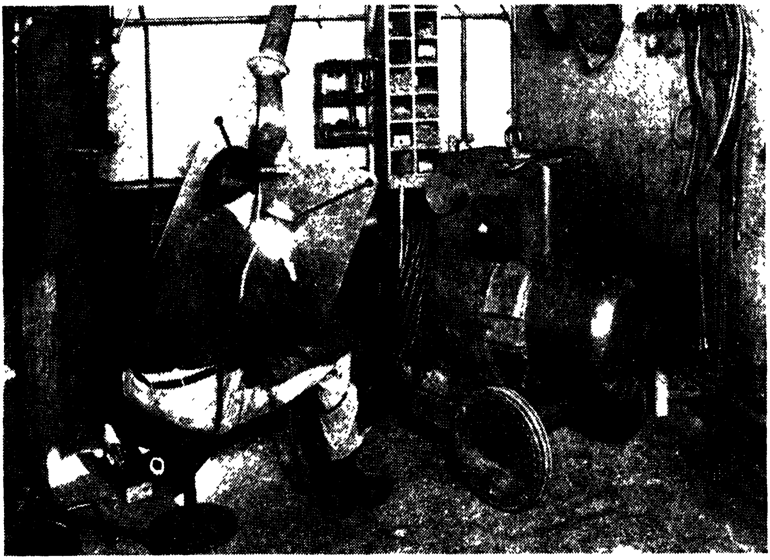


Figure 323. A typical arc welding booth using a turn table, a flexible exhaust vent, a storage rack for electrodes and a D.C. welding machine equipped with an automatic start and stop control. Note the welder's protective clothing
(Courtesy of: DV Welding Controls)

the electrode holder is hung on the arm, the machine is shut off. This device reduces the running idle time of the machine to a minimum. *Figure 321.*

The D-V Automatic Start-Stop welder control is an electrical device using magnetic switches and a timer that starts the D.C. welder when the operator touches the electrode to the work and then stops the machine one to two minutes after the arc is broken. *Figure 322.* It also has a registering device to indicate the welding time. The device, which takes up very little space, can be easily installed. *Figure 323.*

When an operator works on a multitude or a variety of joints and metals, necessitating changes in current, polarity and electrodes, he must usually return to the arc welding machine and adjust it. On occasion he must return several times before the adjustments are correct.

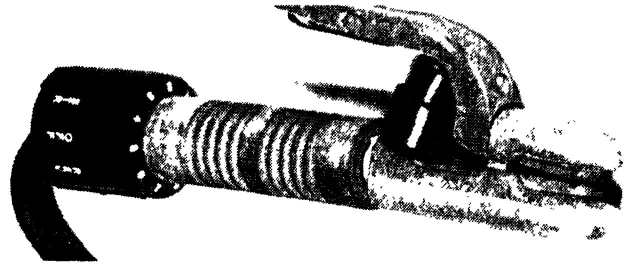


Figure 324. An electrode holder equipped with a convenient stop-start switch, a polarity switch and a five current adjustment. The electrode cable is of special construction which incorporates control wires that lead back to a control box mounted on the D.C. arc welding machine

(Courtesy of: Foster Transformer Company)

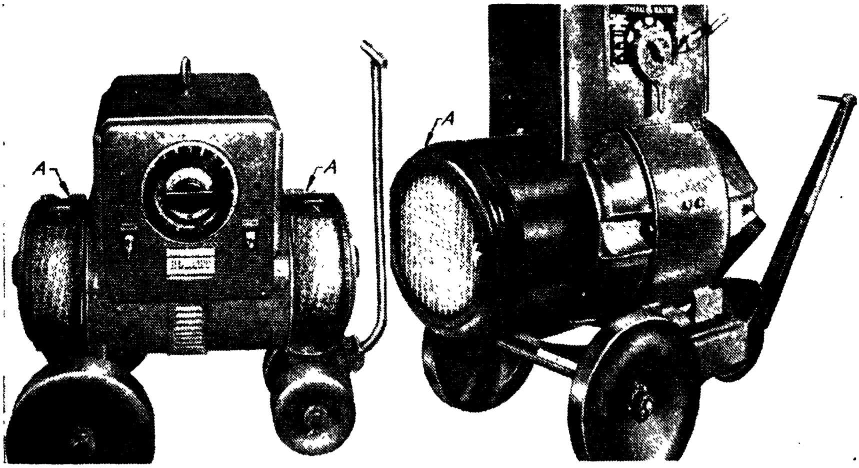


Figure 325. Air filters mounted on the air intake and used to keep the atmospheric and process dirt out of motor-generator arc welders. These filters are cleanable

(Courtesy of: Air Filter Corporation)

To avoid this delay, a complete D.C. welder control device built into the electrode holder is now available. *Figure 324* shows a special welding cable that includes several control wires and an electrode holder with a fine current adjustment, an off and on switch, and a polarity reversing switch.

The operator may climb into restricted places, then turn on the machine, adjust it to any polarity and practically any current setting without having to return to the machine. The saving in time is very important, and better quality welds are also produced because the machine is accurately adjusted to the job requirements at all times.

334. Welding Machine Air Filters

To reduce bearing and commutator maintenance costs to a minimum and to generally increase the high efficiency life of a motor-

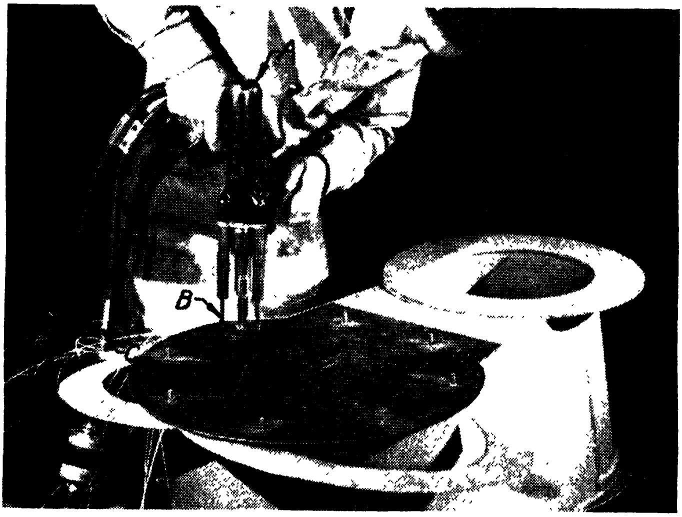


Figure 326. A special stud being welded to a steel structure by means of a stud welding gun (A). Note the tripod (B) for aligning and positioning. The top cable is the welding cable; the bottom cable (C) is the timer cable
(Courtesy of: Nelson Stud Welding Division of Morton Gregory Corporation)

generator arc welder, a filtering accessory has been developed. These filters are made to fit practically all models of arc welders and are cleanable. *Figure 325.* They may be cleaned by blasting with high pressure air, with steam, or rinsing in a commercial solvent.

335. Stud Welding

Stud welding is a special welding development that quickly and efficiently welds studs to steel plates, etc. The process enables one to fasten an assembly device stud to a welded structure and thus fasten different parts together without piercing the metal. This

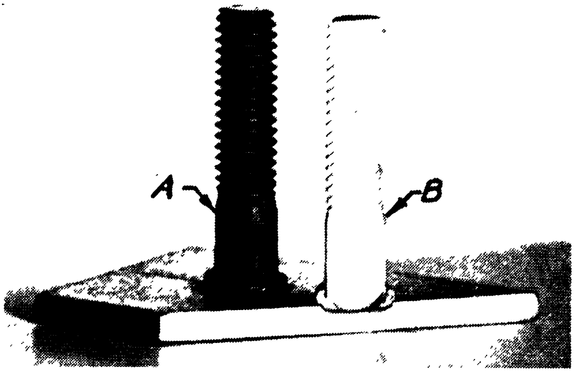


Figure 327. A stud welded to a stud plate: A. shows the complete stud weld, B. shows the stud cross-sectioned to indicate the excellent fusion
(Courtesy of: Nelson Stud Welding Division of Morton Gregory Corporation)

process eliminates drilling or punching holes in the main structure and saves the work of mechanical fastening to the plate, using bolts, rivets or screws. *Figure 326.*

A special gun holds the stud, and an arc is struck between the stud and the main plate. At the end of a definite automatically

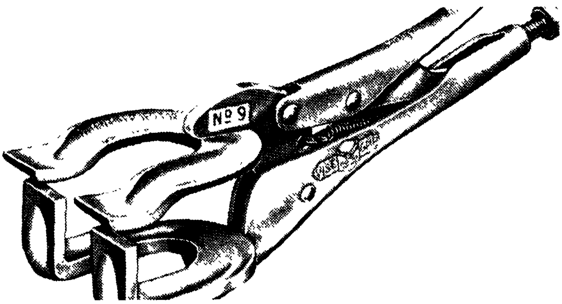


Figure 328. A special clamping and aligning pliers. The two pairs of jaws (one side has deep bends) enables the pliers to clamp, hold, and align weldments during welding
(Courtesy of: Petersen Manufacturing Company)

timed interval, the now molten stud end is forced against the molten metal pool in the plate. *Figure 327.* A ceramic ferrule or collar around the stud holds the molten metal in place and helps form a good fillet. The flux on the end of the stud aids the arc control and enables one to make stud welds in any position. By using appropriate jigs and fixtures, the studs can be placed to an accuracy tolerance as low as .005″ both as to position and height.

336. Welding Clamping Fixtures

The proper holding of parts being welded has always been an important preparation step in welding and brazing. Several efficient and quick methods have been developed to help the operator solve this problem. Pliers with snap jaws of special design for holding and aligning parts are now in use. *Figure 328.* The pliers have deep jaws to enable clamping around obstructions. *Figure 329* shows various applications for this type of clamping pliers.

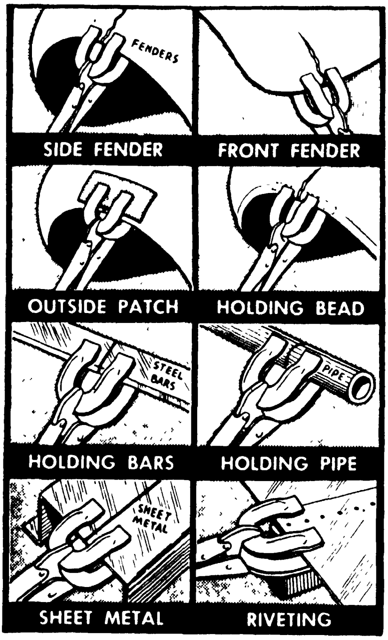


Figure 329. Various applications of the clamping and aligning pliers especially developed for welding
(Courtesy of: Petersen Manufacturing Company)

Clamps of various designs are very convenient for aligning, holding, and positioning various shaped metals. *Figure 330* shows a special double clamp with protractor scales that makes quick aligning of the parts possible.

337. Electrode Holders

The electrode holder illustrated is designed to provide a powerful clamping action on the electrode (screw action) and enables the operator to use up practically all of the electrode. *Figure 331.*

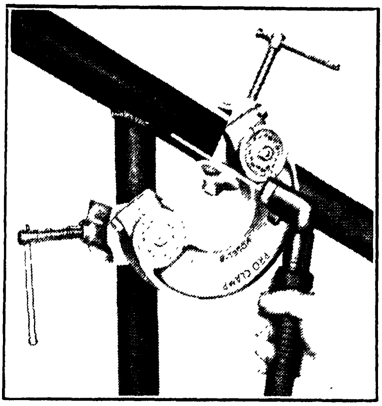


Figure 330. A special welding clamp that holds parts in almost any-position relative to each other. Protractor scales are built into each clamp which enables the operator to accurately adjust the device to any angle
(Courtesy of: Bernard Welding Equipment Company)

338. Air-Acetylene Adaptor

Because the oxy-acetylene flame has a very high temperature, a special adaptor is now available to enable the conversion of the oxy-acetylene torch to an air-acetylene flame for soft soldering. This adaptor, which is very useful in such work as body soldering, is

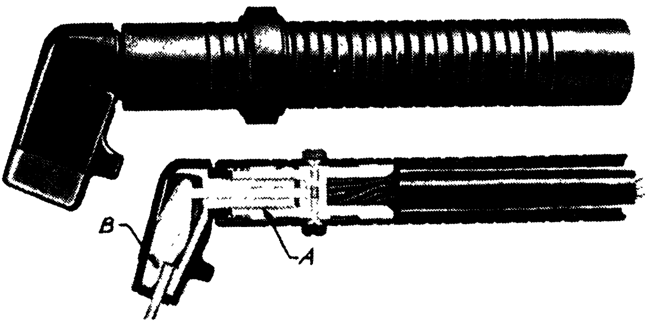


Figure 331. An electrode holder which permits using up more electrode, provides a powerful screw (A) and lever (B) action clamp, and improves visibility for hard to reach welds
(Courtesy of: Bernard Welding Equipment Company)

easily installed and removed. It uses atmospheric air instead of oxygen. The solder is well controlled, as the flame is soft (does not blow) and the heat is spread over a considerable area. *Figure 332.*

339. Tip Cleaners

In order to do a good job of gas welding, it is necessary that the

welding torch tip orifices be in good condition. Back fires, splatter from the puddle, and carbon accumulation in the tip bore may interfere with obtaining a good welding flame. Also the end of the tip may become burred due to its striking the work or other objects. To correct any or all of these faults, the bore of the tip must be cleaned. The recommended cleaning procedure is to use a special tip cleaner. *See Paragraph 288. Figure 333.* The tip is cleaned by

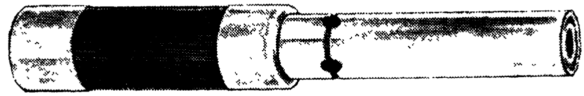


Figure 332. A slip-on soldering tip for welding torches. This tip slips over the regular welding tip and uses acetylene and atmospheric air but no cylinder oxygen. It produces an excellent flame for soldering work of all kinds
(Courtesy of: Anzick Mfg. Company)

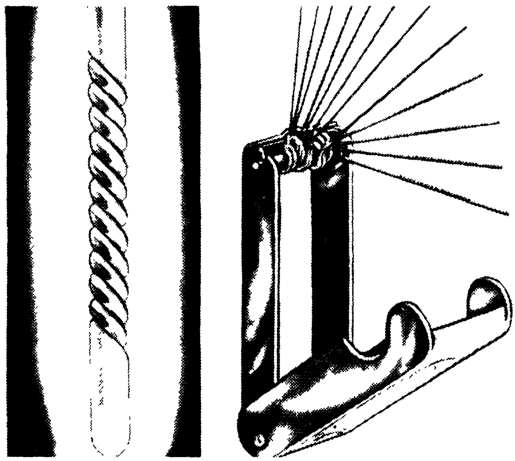


Figure 333. A special set of tip cleaners. The metal container holds a set of these spiral fluted cleaners which do an excellent job of cleaning the tip without injury to the orifice
(Courtesy of: Thermacote Company)

selecting the cleaner the size of the tip orifice and merely inserting and withdrawing it. This cleaner operates as a simple broach. A set of these cleaners may be used in place of drills. *Figure 235.*

340. Welding Copper Cables

To consistently carry the heavy currents used in arc welding, heavy cables, lugs, and connectors are used. However, the operator frequently makes very poor ground connections, and this localized high resistance point makes good welding almost impossible. In a

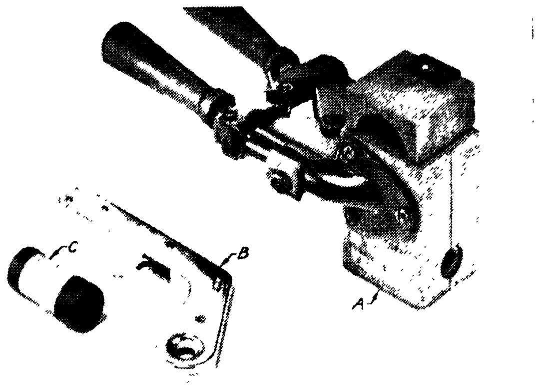


Figure 334. The tools needed to make a fused copper cable splice or cable to lug joint. The graphite mold (A) is sized to fit 2/0 cable. The cover is also graphite. The trigger action spark lighter (B) is a ready means to ignite the charge after the charge is taken from the cartridge (C) and put into (A)
(Courtesy of: Erico Products, Inc.)

similar fashion, many of the cable ends may be poorly connected to the lugs and the like. Mechanical connections, if used, must be tight and clean. Soft soldered connections may be used, but all too frequently are soldered for only 10% to 25% of the electrical flow area.

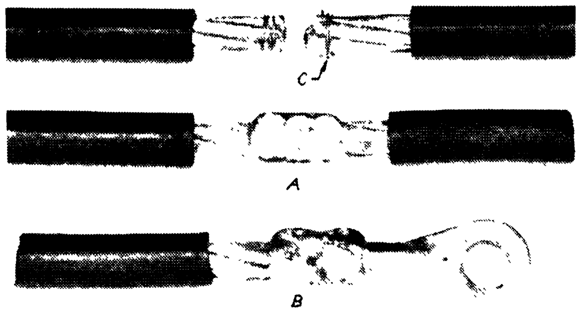


Figure 335. A fused copper cable splice (A) and a cable to lug joint (B). The cable is prepared by removing the insulation and wrapping #14 wire (C) to keep the strands in place during the welding operation
(Courtesy of: Erico Products, Inc.)

Silver brazing may also be used and is excellent if done correctly. A new method of connecting welding cables is the copper welding of the cable ends to lugs or to each other.

The process used is a method of welding copper to copper in which no outside source of heat is required. Powdered copper oxide and powdered aluminum are placed in a small graphite crucible and ignited by means of a spark. The molden copper flows over the

cable ends in the graphite mold; the cable ends become molten, and in a few seconds are securely welded together in a solid homogeneous copper nugget. *Figure 334.*

The cable is prepared by stripping approximately one inch of insulation from each end to be joined. Both ends are then placed in the welder, butted together under the center of the tap hole, and locked by the clamp-type crucible. The flint spark gun ignites the mixture; and in about ten seconds, the weld is completed. The same procedure and equipment may be used to attach terminal lugs. *Figure 335.*

341. Magnetic Ground Attachment

Good ground connections are very important when one is welding

Figure 336. A magnetic ground device for both A.C. and D.C. welders. Permanent magnets (replaceable) hold the ground connection to any surface in any position. It is an easy, quick connection; easily changed in position to reduce arc blow; and it provides good electrical flow

(Courtesy of: Magnetrode Corporation)

either A.C. or D.C. Occasionally the ground cable is permanently fastened to the welding bench or table by bolting or welding. This practice is practical when small pieces are positioned on a table.

Frequently, however, the ground cable must be fastened to the article being welded, due to its size or location. Clamping, bolting, or welding the ground cable to the piece is still practiced on this type of job. These devices frequently are slow, mar the metal being welded, and quite often do not position the ground in an advantageous spot. A magnetic ground is now available which enables one to quickly fasten the ground cable to the work to be welded, makes it easy to change the position of the ground to obtain better

arc characteristics, and also does not injure or mar the article to be welded. *Figure 336.* The ground cable is either soldered or mechanically fastened to this permanent magnet grounding device, and the operator easily positions it on any ferrous surface. The magnets are replaceable and are quite powerful.

342. Sprayed Hard Surfacing

A combined metallizing and welding process is now available which sprays on hard surfacing material which is then fused to the underlying metal with the use of a torch. Since the process is capable of laying on thin coats to accurate depths, the hard sur-

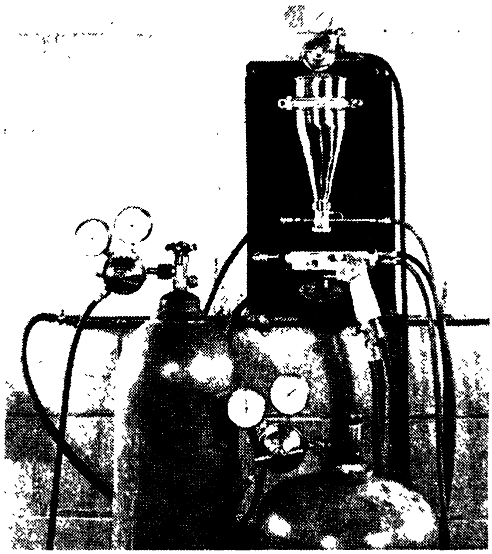


Figure 337. A hard surfacing powder spraying station
(Courtesy of: Wall Colmonoy Corp.)

facing requires practically no grinding or finishing. The apparatus consists of a spray gun, a hard surfacing powder hopper, and a mixer. *Figure 337.* The powder is fed under pressure to the gun; and as it passes through the flame of the gun, it is heated to a plastic state and is impinged onto the metal being hard surfaced. *Figure 338.* The sprayed metal is then heated with an acetylene torch until it fuses to the base metal.

343. Farm Welding

The equipment used for farm welding may be any one of the com-

mon types such as: 1. Oxy-acetylene, 2. D.C. arc, 3. A.C. arc.

Perhaps the most common type of farm welding equipment is the alternating current arc welding transformer, *Figure 83*. This is possible because of the general distribution of electrical power in rural areas. The development of new A.C. electrodes, which provide ironizing elements in their coating, has made the use of small A.C. machines very practical. The A.W.S. E6013 is an example of a rod suitable for most A.C. welding of mild steel on the farm. The characteristics of suitable rods are explained further in Paragraph 310.

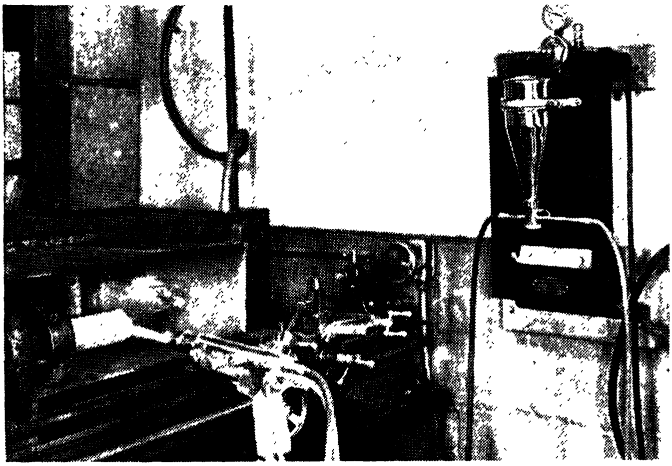


Figure 338. A hard surfacing powder spraying torch applying a layer of hard surface material to round stock that is slowly turning in the lathe
(Courtesy of: Wall Colmonoy Corp.)

The most important factor in connection with farm welding is the correct identification of the particular metal or alloy being welded. If the metal is correctly identified and the proper filler rod or electrode selected, the operation of welding is a very simple matter. The student of farm welding will do well to study Paragraphs 236 through 252 on the properties and identification of metals.

344. Farm Welding Equipment and Supplies

Some of the most frequently used welding equipment and some

of the more frequently used supplies in the Farm Welding Shop are as follows:

*1. Transformer type A.C. welder (check with your Electrical Power Company. It will be economical to use a 220 volt primary)
2. Electrode holder
3. Electrode cables
4. Helmet or shield
5. Leather gloves
6. Mild Steel Electrodes A.W.S. E6011 A.W.S. E6013
7. Special cutting electrodes (for metal cutting)
8. Hard surfacing electrodes
9. Aluminum welding electrodes

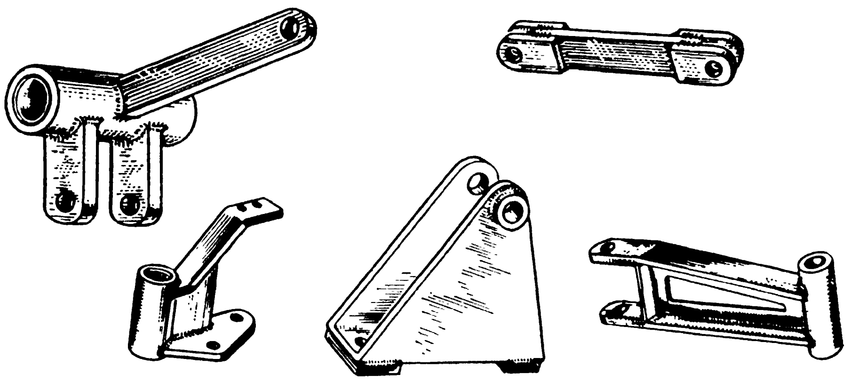


Figure 339. Parts fabricated from flat stock and tubing
(Courtesy of: Lincoln Electric Company)

10. Brazing electrodes
11. Bench grinder
12. ½″ electric drill
13. Chipping and grinding goggles
14. Chipping hammer
15. Fire extinguisher

*The welder must be an Underwriters Laboratories Approved machine. Look for the UL label.

Arc welding machines, gas engine or tractor powered, are now available to furnish emergency A.C. power on the farm in case the electric power system suffers a breakdown. *Figure 318.*

345. Farm Welding Safety

The welding machine should be used in a dry, fire-proof place. Do

not weld while standing on or lying on wet ground, as the open circuit voltage may give you an electrical shock. Floors littered with burnable materials or with cracks that may catch sparks are very dangerous. Always have a fire extinguisher at hand. The carbon dioxide or bicarbonate of soda powder types are good general purpose extinguishers.

Remember to check the job for safety before starting to work!

Keep the electrodes and fluxes clean and dry. Put them in easily identified containers to avoid wrong applications.

346. Farm Welding Applications

There are many special applications of welding equipment on farms in addition to actual welding. For example: rusted screws, bolts, and nuts may be easily removed if they are first heated to a high temperature (cherry red) with either the gas torch or with a carbon arc. Broken screws can be easily removed by welding a nut or a rod to the exposed end of the screw. Paint may be easily removed from metal or wood with a gas torch supplied with a tip to give a fan shaped flame.

Many farm machine parts are made of cast iron or malleable iron. Such parts are difficult to repair unless special rods and fluxes are available. Often it is more satisfactory to fabricate a new part by welding up an assembly of flat stock and tubing. Such parts, if well designed, will often be stronger than the original part.

Figure 339 illustrates some designs of couplers and brackets which are easy to shape and weld.

347. Farm Welding Guide

Classifications	Type of Repair	References See Paragraph
MILD STEEL PARTS Angle iron frames. Pressed steel parts. Parts fabricated from sheet steel or rolled sections such as I beams, channel sections and the like. Pipe.	Weld, Arc, Oxy-Acetylene or Braze.	Electrode sizes Par. 306. Welding procedure Par. 9, 10, 11, 13, 14. Welding tip size Par. 36. Pipe welding Par. 165. Brazing steel Par. 139. Filler rod sizes Par. 317.
EARTH CUTTING IMPLEMENTS Cultivator teeth. Plow shares. Bean puller blades. Potato digger blades.	Hard Surfacing See note (1)	Hard surfacing Par. 157. Hard surface metals Par. 152.

Classifications	Type of Repair	References See Paragraph
Lister shares. Plow points. Implement runners and shoes. Feed mill hammers.		
SPRINGS and RESILIENT MOUNTINGS Fork tines. Spring tooth drag teeth. Automobile bumpers and supports. Tempered shovels.	Braze on a reinforcement. See note (2).	Filler rod information Par. 43. Brazing information and techniques Par. 137, 138, 139. Identification of materials Par. 256. Tempering table Par. 300.
CASTINGS (GRAY IRON) Machine frames. Cast machine parts. Cylinder heads.	Cast iron weld or braze.	Brazing cast iron Par. 141. Properties of cast iron Par. 172. Kinds of cast iron Par. 173. Preparing cast iron for welding Par. 174. Preheating cast iron Par. 176. Welding cast iron Par. 177, 178. Heat treating a cast iron weld Par. 180, 265. Method of strengthening a cast iron weld Par. 175.
CASTINGS (MALLEABLE IRON) Handles and levers. Brackets. Clamps. Sprockets.	Braze only. See note (3).	Kinds of cast iron Par. 173. Brazing malleable iron Par. 141.
CASTINGS ALUMINUM Household utensils. Car and tractor parts.	Aluminum weld. Aluminum braze or solder.	Aluminum welding Par. 153. Aluminum brazing and soldering Par. 301.
CASTINGS (WHITE METAL) (ZINC) Carburetors. Gas filters. Collars. Handles. Non-stressed parts.	White metal weld. See note (4).	Welding die castings Par. 156.

Note (1) Most blades or shares are made of spring or high carbon steel. If the wear is not great, the part may be repaired by the application of some hard surfacing material. If the wear is great, first build up the part with mild steel; then surface the wearing edges with hard surfacing materials, *Figure 340.*

Some plow shares are made of cast iron. To repair worn cast iron plow shares, first build up the worn part with cast iron rod; then surfacing materials that are satisfactory on cast iron. Be sure that the hard surfacing materials used are recommended for hard surfacing cast iron. The initial hard surface on cast iron shares and the like is produced by chilling the casting as it is poured in the foundry.

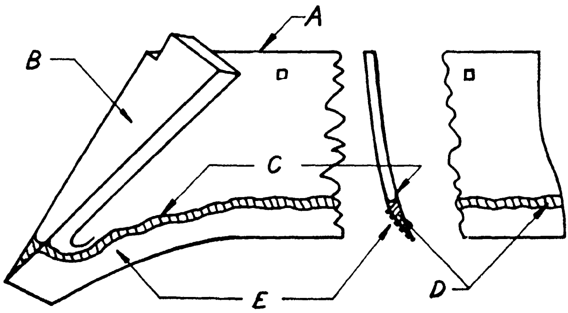


Figure 340. A plow share built up and then hard surfaced: A. the plow share, B. landside, C. old wear line, D. rebuilt by welding, E. hard surfaced

Note (2) Spring steel parts are heat-treated. Welding such parts destroys the heat treatment, and the welded repair will be unsatisfactory. A brazed on reinforcement is the best repair, *Figure 341.* Brazing, if done skillfully, will not destroy the heat treatment of the entire piece. When brazing spring steel parts, it is advisable to cover the parts adjacent to the joint with a wet cloth in order to keep the parts cool and avoid their being annealed.

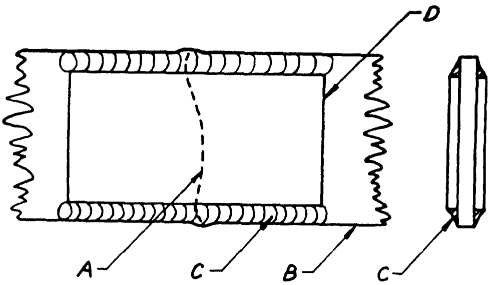


Figure 341. A fractured spring steel part repaired by brazing: A. the fracture, B. the original part, C. the brazed, D. the reinforcement part

Note (3) Malleable iron castings are used for many farm machine parts where greater strength is required than would be possible with cast iron parts, particularly for parts which must stand shock; such parts as sprocket wheels, small clamping castings, and the like. See *Paragraph 237* for methods to identify malleable iron.

Note (4) The beginner should experiment with some scrap white metal parts before attempting to repair a broken part that is to be returned to service. It is very important that the part being welded is well supported since the metal may melt for some distance back from the weld. If carbon blocks or carbon paste is not available, clay or asbestos powder may be moulded around the joint.

347A. Review Questions

1. Of what material is the inert gas arc welding electrode usually made?
2. Why is the inert gas kept flowing after the welding arc is broken?
3. Should one use lighter or darker lens when inert gas arc welding as compared to steel electrode arc welding?
4. How does one strike the arc when using A.C. and an inert gas arc welding torch?
5. How far does the inert gas electrode extend past the end of the cup?
6. Is flux necessary when inert arc gas welding aluminum? Why?
7. Is it possible to automatically weld with inert arc gas welding?
8. What is the popular filler rod angle when inert gas arc welding?
9. What is inert gas spot welding?
10. How is the inert gas arc welding electrode holder or torch cooled?
11. Name two popular inert gases.
12. What are the three main classifications of stainless steels?
13. Which stainless steels are magnetic?
14. What is the purpose of titanium in stainless steel filler rods?
15. Is it possible to arc weld stainless steel?
16. What institute standardized the types of stainless steel?
17. Why is a flux necessary when gas welding stainless steel?
18. How may one arc weld stainless steel without using a flux or a coated electrode?
19. Who has standardized the electrodes by number?
20. What is the approximate tensile strength of an E-6010 welded joint?
21. How many classifications of positions are listed in the electrode numbers?
22. What is the difference between E-6010 and E-6011 electrodes?
23. List the tensile strength, the welding position, and the type of coating of an E-7016 electrode.
24. What is the flow temperature of the aluminum brazing alloy?
25. How is the arc length indicated in submerged arc welding?
26. What type electrode is used in arc-oxygen cutting?
27. How accurately can one cut with an automatic machine?

28. Describe powder cutting.
29. How is the flux introduced into the kerf when flux cutting?
30. How deep underwater may one safely perform oxy-acetylene cutting?
31. May one cut underwater with an arc-oxygen torch?
32. What should be the appearance of the flux when one adds filler rod during silver brazing?
33. Is it possible to make a silver brazed joint at the same cost as a welded joint? Explain.
34. What is the special silver alloy used when silver brazing copper?
35. May any of the flux be salvaged when one makes a submerged arc weld?
36. List one advantage of submerged arc welding.
37. May one make a manual submerged arc weld?
38. What type electrode is used when making a submerged arc weld?
39. What kind of current is produced by a selenium rectifier arc welding machine?
40. Why are some welding machines gas engine powered?
41. What kind of auxiliary current do some gas engine powered arc welders produce?
42. Describe a remote control for a D.C. arc welding machine.
43. What is meant by the term "air-hardening" tool steel?
44. What is the purpose of peening a tool steel weld?
45. Explain the difference between preheat and post heat.
46. Is metal spraying used for hard surfacing? Explain.
47. What is the most practical weld repair for malleable iron?
48. How may one repair a broken spring fork?
49. Why are clamps used when welding?
50. How may one connect a ground cable to a weld structure quickly and without injuring the surface in any way?
51. What type of equipment for welding aluminum doesn't require a flux?

CHAPTER XX

TECHNICAL DATA

348. The Chemistry of Welding

Chemical formula of combustion of Acetylene and Oxygen.

Acetylene = $C_2 H_2$
Oxygen = O_2
Carbon Monoxide = $C O$
Carbon Dioxide = $C O_2$
Water (Vapor) = H_2O
$2 C_2 H_2 + 3 O_2 = 4 C O + 2 H_2 O$ + Heat

It may be noticed from the above equation that in the neutral flame the carbon unites with the oxygen to form carbon monoxide. Carbon monoxide is unstable and will unite with oxygen to form carbon dioxide. This accounts for the fact that surrounding the cone of the flame is an area of flame of lesser intensity in which the carbon monoxide is united with atmospheric oxygen to form carbon dioxide. The layer of carbon monoxide tends to keep the molten weld metal from oxidizing, as it absorbs any free oxygen present.

The chemical action in the outer flame becomes:

$2 C O + O_2 = 2 C O_2$ + heat

The oxygen in this case comes from the atmosphere surrounding the flame.

This principle must be remembered when welding in a confined space in which a free movement of air cannot exist above the torch tip; under these conditions more oxygen will need to be fed to the torch tip in order that a carbonizing flame may be attained.

349. Definition of Terms

AC or Alternating Current is that kind of electricity which reverses its direction periodically. The period of alternating depends upon the cycle of the current. For 60-cycle current, the current goes in one direction and then in the other direction 60 times in the same second so that the current changes its direction 120 times in one second.

Acetylene is a gas composed of two parts of carbon and two parts of hydrogen; when burned in an atmosphere of oxygen, it produces one of the highest temperatures obtainable in using gases. (630° F.)

Acetylene Cylinder is a specially built container manufactured according to I.C.C. Standards used to store and ship certain amounts of acetylene.

Acetylene Hose. (See Hose.)

Acetylene Regulator is an automatic valve used to reduce cylinder pressures to torch pressures and to keep these pressures constant. They are never to be used as oxygen regulators.

Alloy is an intimate mixture of two or more metals.

Annealing means to soften metals by heat treatment; it most commonly consists of heating the metals up to a near-molten state and then cooling them very slowly.

Arc is the term given to the flow of electricity through a gaseous space or air gap; in arc welding it is this flow of electricity through the air which produces high temperatures.

Arc Welding means fusing two metals together by means of an electric arc.

Backward Welding is welding in the direction opposite the direction the gas flame is burning or pointing.

Bead denotes the appearance of the finished weld; it describes the neatness of the ripples formed by the metal while it was in a semi-liquid state.

Body is a term applied to the main structural part of a regulator.

Blow pipe is another term applied to the oxy-acetylene torch.

Brazing is the term applied to that type of soldering in which brass is used as the connecting medium between two metals.

Burned metal is the term occasionally applied to the metal which has been combined with oxygen to the end that some of the carbon has been changed into carbon dioxide and some of the iron into iron oxide.

Burning is the violent combination of oxygen with any substance producing heat.

Butt Weld is a weld in which the two pieces of metal to be joined are placed in the same plane with the edge of one piece touching the edge of the other.

Carbon is an element which when combined with iron forms various kinds of steel. When in steel, it is the carbon which is oxidized (combined with the oxygen), leaving the physical properties of the steel changed. It is used in a solid form as an electrode for arc welding or as a mold.

Carbonizing is the term applied to the addition of carbon to any metal.

Carburizing has the same meaning as carbonizing in the welding industry.

Cone is the term applied to the shape of the gas welding flame.

Cracking is the term applied to the action of opening a valve slightly and then closing the valve immediately.

Crown is the curve, or the convex surface, of the finished weld proper.

Case Hardening is adding carbon to the surface of a mild steel object and heat testing to produce a hard surface.

Castings are those metallic forms which are produced by pouring molten metal into a shaped container. (Mold.)

Cylinder. (See Oxygen, see Acetylene.)

DC or Direct Current is that kind of electric current which flows only in one direction along the wire.

Electrode is a substance which brings electricity up to the point where the arc is to be formed; in other words it is the material immediately adjacent to the arc proper and the one which carries the current to this point. In electric arc welding the electrode is melted and becomes a part of the weld.

Filler Rod is the metal wire that is melted and added to the welding puddle to produce the necessary increase in bead thickness.

Fillet is to fill in the internal vertex, or corner, of the angle formed by two pieces of metal, giving the joint additional strength for unusual stresses.

Forgings are metallic shapes being derived by either hammering or squeezing the original piece of metal into the desired shapes or thicknesses.

Forward Welding is fusing the metal in the same direction as the torch flame points.

Flash is the impact of the electric arc rays against the human eye. Also the fin of surplus metal formed at the seam of a resistance weld.

Flat Weld is a horizontal weld on a horizontal surface.

Flux is a chemical used to promote fusion of metals during the welding process.

Generator is a mechanism which generates or produces some substance, i.e., electric generator and acetylene generator.

Hand Shield. (See Shield.)

Helmet is a protecting hood which fits over the arc welder's head, provided with a lens of safety glass through which the operator may observe the electric arc.

Horizontal weld is a weld performed on a horizontal seam on a vertical surface.

Hose is the flexible medium used to carry gases from the regulator to the torch. It is made of fabric and rubber.

Hydrogen is a gas formed of the single element hydrogen, and is considered one of the most active gases. When combined with oxygen, it forms a very clean flame which, however, does not produce a very high temperature or very much heat.

Infra Red Rays are heat rays which emanate from both the arc and the welding flame.

Inside Corner Weld is a fusion of two metals together, one metal being held 90° to the other; the fusion is performed inside the vertex of the angle.

Lap Weld has the edges of the two metals to be joined lapped one over the other to form a joint for welding.

Lens is a specialty treated glass through which one may look at an intense flame without being injured by the harmful rays, or glare, radiating from this flame.

Malleable castings are cast forms of metal which have been heat-treated to reduce their brittleness.

Mixing Chamber is that part of the welding torch wherein the welding gases are intimately mixed, prior to their combustion.

Negative connections are those connections in an electric circuit through which the current flows back to its source.

Neutral Flame results from the combustion of the perfect proportions of oxygen and the welding gas.

Orifice is that opening through which gases flow. It is usually the final opening, or any opening controlled by a valve.

Outside Corner Weld is fusing two pieces of metal together, with the fusion taking place on the under-part of the seam.

Oxidizing is combining oxygen with any substance. For example, a metal is oxidized when the metal is burned i.e., oxygen is combined with all of the metal or parts of it.

Oxidizing Flame is an excess of oxygen in the torch mixture, leaving some free oxygen which tends to burn the molten metal.

Oxy-Acetylene Welding. (See Oxygen-Acetylene.)

Oxygen Acetylene Cutting is cutting metal using the oxygen jet which is incorporated with an oxygen-acetylene, pre-heating flame or flames.

Oxygen is a gas formed of the element oxygen, which very actively supports combustion.

Oxygen-Acetylene Welding is a method of welding, using as a fuel a combination of the two gases—oxygen and acetylene.

Oxygen Cylinder is a specially built container manufactured according to I.C.C. Standards and used to store and ship certain amounts of oxygen.

Oxygen Hose. (See Hose.)

Oxygen Regulator is an automatic valve used to reduce cylinder pressures to torch pressures and to keep these pressures constant. They are never to be used as acetylene regulators.

Penetration means to fuse the metals throughout their thickness at the point of their joining.

Positive connections are those connections in an electric circuit out of which electricity flows constantly. The positive connections out of which electricity flows may also be termed that into which the electrons flow; and the negative connection into which the electricity flows may be considered that pole out of which the electrons flow.

Puddle is that portion of a weld that is molten at the place the heat is supplied.

Rays. (See Infra Red and Ultra violet.)

Regulators. (See Acetylene, see Oxygen.)

Shield is an eye and face protector carried in the hand; and it enables a person to look directly at the electric arc through a special lens without being harmed. Shield arc is a form of Electric Welding in which a heavy Flux coated electrode is used.

Soldering is the means of fastening metals together by adhering another metal to the two pieces of any other metal which is not melted during the operation.

Tee is to place one metal against another at a 90° angle to each other with the edge of one metal contacting the surface of the other metal.

Tinning is the term applied to soldering where the metals to be soldered together are first given a coating of the soldering metal.

Tip is that part of the torch at the end of which the gas burns, producing the high temperature flame. In resistance welding the electrode ends are sometimes called tips.

Torch is the name given to the mechanism which the operator holds during gas welding and at the end of which the gases are burned to perform the various gas welding operations.

Ultra violet rays are energy waves that emanate from the electrodes and the welding flames.

Vertical weld is that type of weld where the welding has to be done on a vertical seam and on a vertical surface.

Welding is the art of fastening metals together by means of interfusing them.

350. TEMPERING TABLE
(Courtesy of: Champion Rivet Company)

Temperature for 1 Hour		Color	Temperature 8 Min.		Suggested Uses
F.	C.		F.	C.	
370	188	Faint Yellow	460	238	Scrapers, brass turning tools, reamers, taps, milling cutters, saw teeth.
390	199	Light Straw	510	265	Twist drills, lathe tools, planer tools, finishing tools.
410	210	Dark Straw	560	293	Stone tools, hammer faces, chisels for hard work, boring cutters.
430	221	Brown	610	321	Trephining tools, stamps.
450	232	Purple	640	337	Cold chisels for ordinary work, carpenters' tools, picks, cold punches, shear blades, slicing tools, slotter tools.
490	254	Dark Blue	660	349	Hot chisels, tools for hot work, springs.
510	265	Light Blue	710	376	Springs, screw drivers.

351. OXYGEN—TEMPERATURE EFFECTS: TABLE SHOWING EFFECT OF TEMPERATURE UPON THE PRESSURE IN A FULL CYLINDER OF OXYGEN

Temperature of Oxygen	Gauge Reading Lbs. Per Sq. In.
100	2147
90	2098
80	2049
70	2000
60	1951
50	1902
40	1853
30	1804
20	1755
10	1706
0	1657

352. Wire Gauges: Wire and Sheet Metal Gauges Compared
(Courtesy of: Champion Rivet Company)

Number of Gauge	Number of Gauge	U. S. Standard Gauge For Steel and Plate Iron and Steel, 1893	American or Brown and Sharpe Gauge
		Inch	Inch
0000000	7/0	.5	. . . .
000000	6/0	.469	. . . .
00000	5/0	.438	. . . .
0000	4/0	.406	.46
000	3/0	.375	.40964
00	2/0	.344	.3648
0	0	.313	.32486
1	1	281	.2893
2	2	.266	.25763
3	3	.25	.22942
4	4	.234	.20431
5	5	.219	.18194
6	6	.203	.16202
7	7	188	.14428
8	8	.172	.12849
9	9	.156	.11443
10	10	.141	.10189
11	11	.125	.09074
12	12	.109	.08081
13	13	.094	07196
14	14	.078	.06408
15	15	.07	.05707
16	16	.0625	.05082
17	17	.0563	.04526
18	18	.05	.0403
19	19	.0438	.03589
20	20	.0375	.03196
21	21	.0344	.02846
22	22	.0131	.02535
23	23	.0281	.02257
24	24	.025	.0201
25	25	.0219	.0179
26	26	.0188	.01594
27	27	.0172	.01419
28	28	.0156	.01264
29	29	.0141	.01126
30	30	.0125	.01002

353. Welding Cable: N. E. M. A. Standard E. W. 8-92 Cable Sizes For Use With Standard Welders

(Courtesy of: Champion Rivet Company)

Ampere Rating of Welder	Cable Size S. W. G.
75	4
100	2
200	2
300	0
400	00
600	000

The above table is for welding cable up to 90 feet in length, that is, 45 feet of welding cable and 45 feet of return or ground cable.

354. Properties of Elements and Metal Compositions

(Courtesy of: Champion Rivet Company)

Elements	Symbol	Melting Temperature Fahr.	Melting Temperature Cent.	Density (Specific) (Gravity)	Weight Per Cub. Foot	Specific Heat
Aluminum	Al	1,218	659	2.7	166.7	0.212
Antimony	Sb	1,166	630	6.69	418.3	0.049
Armco Iron		2,795	1,535	7.9	490.0	0.115
Carbon	C	6,510	3,600	2.34	219.1	0.113
Chromium	Cr	2,770	1,520	6.92	431.9	0.104
Columbium	Cb	3,124	1,700	7.06	452.54	
Copper	Cu	1,980	1,100	8.89	555.6	0.092
Gold	Au	1,900	1,060	19.33	1205.0	0.032
Hydrogen	H	—434.2	—259	0.070	0.00533	
Iridium	Ir	4,260	2,350	22.42	1400.0	0.032
Iron	Fe	2,790	1,530	7.865	490.9	0 115
Lead	Pb	621	327	11.37	708.5	0.030
Manganese	Mn	2,300	1,260	7.4	463.2	0.111
Mercury	Hg	—38	—39	13.55	848.84	0.033
Nickel	Ni	2,650	1,450	8.80	555.6	0.109
Platinum	Pt	3,190	1,750	21.45	1336.0	0.032
Silicon	Si	2,590	1,420	2.49	131.1	0.175
Silver	Ag	1,800	960	10.5	655.5	0.055
Tin	Sn	450	232	7.30	455.7	0.054
Titanium	Ti	3,270	1,800	5.3	218.5	0.110
Tungsten	W	5,430	3,000	17.5	1186.0	0.034
Uranium	U	....	....	18.7	1167.0	0.028

354. PROPERTIES OF ELEMENTS AND METAL COMPOSITIONS (*Continued*)

Elements	Symbol	Melting Temperature		Density (Specific) Gravity	Weight Per Cub. Foot	Specific Heat
		Fahr.	Cent.			
Vanadium	V	3,130	1,720	6.0	343.3	0.115
Zinc	Zn	787	419	7.19	443.2	0.093
Bronze (90Cu 10sn)	...	1562-1832	850-1000	8.78	548.0	....
Brass (90Cu 10Zn)	...	1868-1886	1020-1030	8.60	540.0	....
Brass (70Cu 30Zn)	...	1652-1724	900-940	8.44	527.0	....
Cast Pig Iron	...	2012-2282	1100-1250	7.1	443.2	....
Open Hearth Steel	...	2462-2786	1350-1530	7.8	486.9	....
Wrought Iron Bars	...	2,786	1,530	7.8	486.9	....
Lithium	...	367	186	....	......	....
Silenium	...	424	218	....	......	....
Bismuth	...	520	271	....	......	....
Thallium	...	576	302	....	......	....
Cadmium	...	610	321	....	......	....
Tellurium	...	846	452	....	......	....
Cerium	...	1,184	640	....	......	....
Magnesium	...	1,204	651	....	......	....
Barium	...	1,600	850	....	......	....
Cobalt	...	2,700	1,480	....	......	....
Palladium	...	2,820	1,550	....	......	....
Zirconium	...	3,090	1,700	....	......	....
Thorium	...	3,090	1,700	....	......	....
Rhodium	...	3,540	1,950	....	......	....
Boron	...	3,990	2,200	....	......	....
Ruthenium	...	4,440	2,450	....	......	....
Molybdenum	...	4,530	2,500	....	......	....
Osmium	...	4,890	2,700	....	......	....
Tantalum	...	5,160	2,800	....	......	....

355. Heat and Temperature

The Molecular Theory of heat is generally accepted by chemists and engineers as the best explanation of heat energy. The three most important forms of energy are heat energy, mechanical energy, and electrical energy. It is well known that one form of energy can be easily converted into another form of energy. For example: an electric motor may be used to turn electrical energy

into mechanical energy. The bearings of this motor warm up a little while it is running, showing that some of the mechanical energy is being turned into heat. Thorough research has shown that:

One-horse power (mechanical energy) equals 2545.6 B.t.u. per hour (heat energy)

One-horse power (electrical energy) equals 746 watts

Therefore, 746 watts equals 2545.6 B.t.u. per hour

1 watt equals 3.412 B.t.u. per hour

1 kw equals 3412 B.t.u. per hour

The Molecular Theory of heat, briefly explained, is as follows: All matter consists of molecules and atoms; atoms further consist of protons and electrons. It is believed that these molecules, atoms, etc., are always in motion. That is, the molecule in a sheet of paper is continually in motion and that the rapidity with which it moves determines the amount of heat energy in the sheet of paper.

The rapidity with which the molecule moves determines the heat level or intensity of heat and is known as temperature. Whether one atom is moving at a certain speed, or whether a thousand atoms are moving at the same speed, the temperature will be the same. It is, therefore, necessary to know the number of molecules, or atoms, in a substance to determine the total amount of heat energy stored in that substance. This in brief is the difference between temperature and the amount of heat. It may be seen from the above that to know the temperature one needs to know only the speed of molecule motion. But to know the amount of heat in the substance one must know both the temperature and the weight of the substance.

As everyone knows all substances may exist in three forms, solid, liquid, and gas. It is usually conceded that there is no change in the chemical composition of the same substance in any of these three forms. It is, therefore, explained that in a particular substance in the solid form, the molecules have a vibrating motion. They stay in the same position relative to each other, but they are vibrating. When energy is applied to the substance, the molecules vibrate faster than before and this is indicated by an increase in temperature. However, only a certain definite amount of heat energy may be put into the substance, and only a certain temperature rise can be obtained in a solid. After this amount has been absorbed by the substance, if any additional energy is added the molecules will travel at such a rate that the molecules cannot stay within their vibrating bonds. At this heat level an internal change of structure occurs within the molecule, accompanied by considerable absorp-

tion of energy, and the substance changes slowly from the solid to the liquid state. The substance will absorb heat during the transformation, but there is no temperature rise. All the heat being applied, regardless of how fast or slow, produces the internal structural change, rather than an increase of the motion of the molecule.

The theory of the energy in a liquid substance is that the molecule now travels in a straight line until it comes into contact with another molecule, instead of vibrating. This necessarily means that the substance will now have no definite shape and will have no rigidity. It must, therefore, be kept in a container. However, the structure of the molecule is such that the individual molecules still have considerable attraction one for the other; one molecule will attract another enough to divert its path and also to prevent it from traveling too far apart.

As energy is applied to the liquid molecule, the rate of travel increases and this is indicated by a temperature rise (increase in the heat level). After a certain amount of energy has been absorbed by the liquid, it will reach a certain heat level of temperature, where energy applied results not in a temperature change, but in an internal structure change of the molecule with the result that the liquid now turns into a gas. While heat is being turned into the gas, the temperature cannot rise inasmuch as the heat being applied results only in a structural change. Upon becoming a gas, the molecules lose their attraction one for the other and travel in straight paths until contacting another molecule or some other substance. This means that gas must be confined to sealed containers.

Ice, water, and steam are the best examples of the above theory. All three conditions are easily obtained, and changing from one to the other does not reveal any change in chemical composition.

The welding industry is interested in the energy in heating gases; it is interested in turning solids to liquids and, therefore, the welders should know some of the theory of molecular energy.

The heat which turns solids to liquids, liquids to solids, liquids to gases, or gases to liquids is called latent heat (hidden heat) because the thermometer gives no indication of the amount of this heat. For example, it requires 970 B.t.u. per lb. of water to change from water at 212° F. While welding, one may sometimes note that a certain sized tip on a particular welding job heats the metal to the melting point, but it has difficulty in actually melting the metal. This shows that the torch tips must be large enough to heat the metal, and must also furnish enough heat to supply the latent heat (heat of fusion).

356. Steel Welding Electrodes: Welding Wire Sizes Suggested for Welding Steel of Different Thicknesses

Steel		
Material Thickness	Wire Size	Wt.—Lbs. Per Ft.
Inches		
3/32—1/8	16 ga.	.0105
1/8—5/32	14 ga.	.0171
5/32—1/4	1/8	.0418
1/4—1/2	3/16	.0939
1/2—3/4	1/4	.167
3/4—1	...	..
Extra Heavy	5/16	.260

357. Cast Iron Welding Electrodes: Welding Wire Sizes Suggested for Welding Cast Iron of Different Thicknesses

Cast Iron		
Material Thickness	Wire Size	Wt.—Lbs. Per Foot
Inches		
1/4—1/2	3/16	.120
1/2—3/4	1/4	.175
3/4—1	3/8	.380
Heavy Castings	1/2	.675

Electrode Sizes

Material Thickness	Electrode Diameter	Wt.—Lbs. Per Ft.
Inches		
1/8	1/8	.053
3/16, 1/4, 5/16, 3/8	5/32	.0663
1/2	3/16	.094
3/4, 1	1/4	.167

358. METAL PROPERTIES: PROPERTIES OF VARIOUS METALS

Metal	Weight Per Cu. Ft. in Pounds	Expansion for Each 1°F. Rise in Temperature in .00001 Inches
Aluminum	165	1.360
Brass	520	1.052
Bronze	555	.986
Copper	555	.887
Gold	1200	.786
Iron (Cast)	460	.556
Lead	710	1.571
Nickel	550	.695
Platinum	1350	.479
Silver	655	1.079
Steel	490	.689

359. Chemical Reactions in the Manufacture of Iron and Steel

Pig iron, now graded by chemical analysis, is the starting product for wrought iron, cast iron, malleable iron and steel.

Cast Iron

Cast iron is pig iron remelted and somewhat refined in Cupola, and cast in its final form.

Wrought Iron

Wrought iron is produced in a puddling furnace.

Wrought iron is refined at a temperature below the melting temperature.

Wrought iron is quite pure iron but contains slag.

Puddling Furnace

Pig iron is charged into hearth and melted.

Iron ore is charged into hearth and heating continues.

$$3\,Si + 2\,Fe_2O_3 \rightarrow 4\,Fe + 3\,S{\cdot}O_2 + A$$

$$3\,Mn + Fe_2O_3 \rightarrow 2\,Fe + 3\,MnO + A$$

after enough heat is produced then

$$3\,C + Fe_2O_3 \rightarrow 2\,Fe + 3\,CO + A$$

$$3\,CO + 3/2\,O_2 \rightarrow 3\,CO_2 + A$$

Phosphorus and Sulphur cannot be removed in this process.

The melting point is lowered as impurities are burned out and metal becomes pasty and is puddled into balls 100-200 lbs. and passed through rollers to squeeze out the slag.

The composition of pig iron as compared to wrought iron or steel is listed as follows:

	Pig Iron	W. Iron or Steel
Total Carbon (C)	3.5 to 4.25%	.02 to 1.6%
Silicon (Si)	1 to 3%	.01 to .30%
Manganese (Mn)	.5 to 1%	.01 to 1%
Sulphur (S)	.06-	.04 to .06%
Phosphorus (P)	.08 to 1%	.04 to .10%
Iron (Fe)	91 to 94%	99%

W. Iron contains 1-3% slag

360. Blast Furnace Reaction (Chemical)

The Main reactions in Blast Furnace

1. $C + O_2 \rightarrow CO_2 + A$
2. $CO_2 + C \rightarrow 2\ CO - A$

in lower zone of furnace

3. $Fe_2O_3 + 3\ CO \rightarrow 3\ CO_2 + 2\ Fe + A$
4. $MnO + CO \rightarrow CO_2 + Mn + A$
5. $SO_2 + CO \rightarrow CO_2 + Si + A$

in upper zone of furnace

The Al_2O_3, CaO, MnO go through both zones unchanged as not enough is furnished to cause these (4) & (5) reaction to go to completion.

6. $Fe_2O_3 + 3\ C \rightarrow 3\ CO + 2\ Fe - A$ in lower zone as much heat is required
7. $CaCO_3 + A \rightarrow CaO + CO_2$ in upper part and go practically to completion
8. $MgCO_3 + A \rightarrow MgO + CO_2$
9. $CaSO_4 + 2\ C \rightarrow CaS + 2\ CO_2$ in lower zone and only partly complete
10. $CaO + Al_2O_3 \rightarrow CaO\ .\ Al_2O_3$
11. $CaO + S{:}O_2 \rightarrow CaO\ .\ S{\cdot}O_2$

MgO will form similar products. These products plus CaS form the slag.

SUMMARY

$CaCO_3 + A \rightarrow CaO + CO_2$
$MgCO_3 + A \rightarrow MgO + CO_2$
$Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$ in reduction or upper zone
$SiO_2 + 2\ CO \rightarrow Si + 2\ CO_2$
$MnO + CO \rightarrow Mn + CO_2$

$C + O_2 \rightarrow CO_2$
$CO_2 + C \rightarrow 2\,CO$
$Fe_2O_3 + 3\,C \rightarrow 3\,CO + 2\,Fe$
$CaO + Al_2O_3 \rightarrow CaO\ .\ Al_2O_3$ in lower or melting zone
$CaO + S.O_2 \rightarrow CaO.\ S.\ O_2$
$CaSO_4 + 2\,C \rightarrow CaS + 2\,CO_2$

Pure Iron melts at 2700° F.

Iron containing impurities melts at a much lower temperature.

Iron and slag separate in bottom of blast furnace because slag being much lighter floats on top of the molten iron. Impurities such as Silicon Manganese and Carbon are soluble in iron, hence remain in iron. Iron Sulphide and Iron Phosphide are also soluble in iron so must be kept as low as possible.

Blast Furnace (see illustration).

Blast Furnace, in production of pig iron, must:

1. Deoxidize the iron ore.
2. Melt the iron.
3. Melt the slag.
4. Carbonize the iron.
5. Separate the iron from the slag.

Blast Furnace

The charge of the furnace and the materials resulting are tabulated below:

	Materials In	Pig Iron	Materials Out	
			Slag	Gas
	Fe_2O_3	Fe	Al_2O_3	CO_2
	SiO_2	C	CaO	N_2
ORE	Al_2O_3	Si	SiO_2	CO
	MnO	FeS	CaS	
	$CaSO_4$	Fe_3P		
	$Ca_3(PO_4)_2$			
	$MgCO_3$			
FLUX	$CaCO_3$			
FUEL	C			
AIR	O_2 plus N_2			

361. History of Iron Making

3000 B.C., Egyptians used wrought iron.
Romans know how to make iron.
1500 B.C., Catalan Forge.
14th Century, Europeans had a simple blast furnace.

1618—Coke was introduced as a fuel.
1828—Nielson introduced the hot blast.
1880—Greatest improvement in blast furnace.

Raw Materials for Blast Furnace

Oxides of iron used as sulphides are too difficult to separate from their sulphur content.

All iron oxides are contaminated with clay and sand.

Types of Ores Used:

Hematite (red iron) Fe_2O_3	70% iron
Magnetite (black) Fe_3O_4	72.4% iron
Limonite (brown) Fe_2O_3 H_2O	60% iron
Siderite Iron Carbonate $FeCO_3$	48.3% iron

Hematite most important ore in U. S. It all comes from Birmingham and the Lake Superior district.

Marquette range
Menominee range
Gogebic range
Vermillion range
Missabe range
Cayuna range 45% Manganese (ferro manganese)

FLUX

A good flux must melt and unite with impurities, called gangue, and carry them away in form of slag.

Sand and Alumina are chief impurities. (Acid)
Flux is Limestone. (Basic).

FUEL

Must melt the charge and furnish heat for the reactions in the furnace and must be low in phosphorus and sulphur. Coke is the best fuel.

362. Heat Treating Aluminum

To regain most of the original strength of duralumin (17S alloy) it must be carefully heat treated. Heat the metal in a carefully controlled furnace 900° F. to 940° F. and then quench in water. The result is a soft ductile metal which hardens (ageing) increases in strength and brittleness for several days. A typical heat treated 17S alloy will have a strength of 6,000 pounds per sq. inch. While

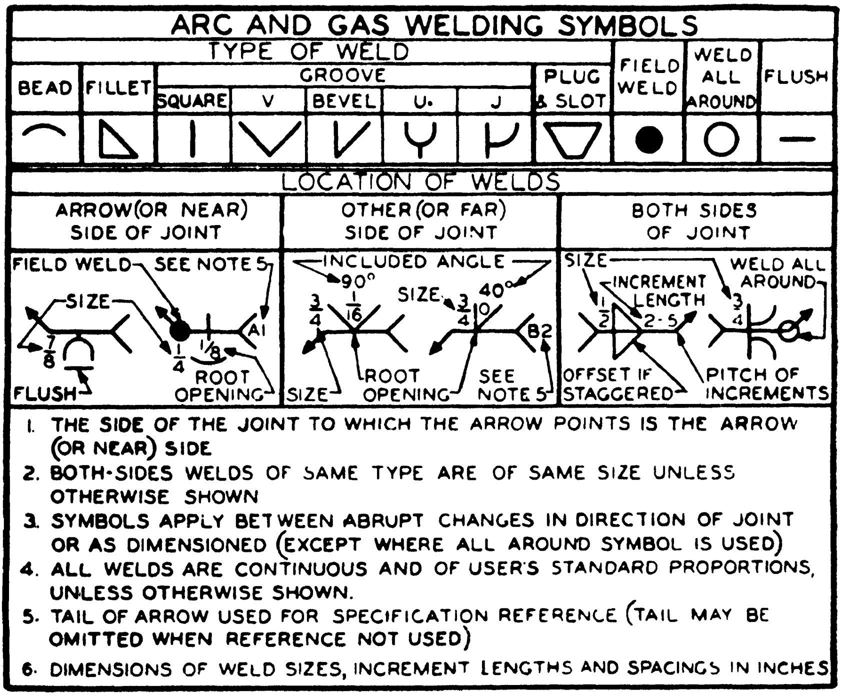
special alloys may go as high as 73,000 pounds per sq. inch. A 17S alloy contains approximately the following:

92% aluminum
4% copper
.5% magnesium
.5% manganese
and traces of silicon and iron.

Some other aluminum alloys are the aluminum-manganese, alloy aluminum, manganese, copper alloy and the aluminum, copper, silicon alloy.

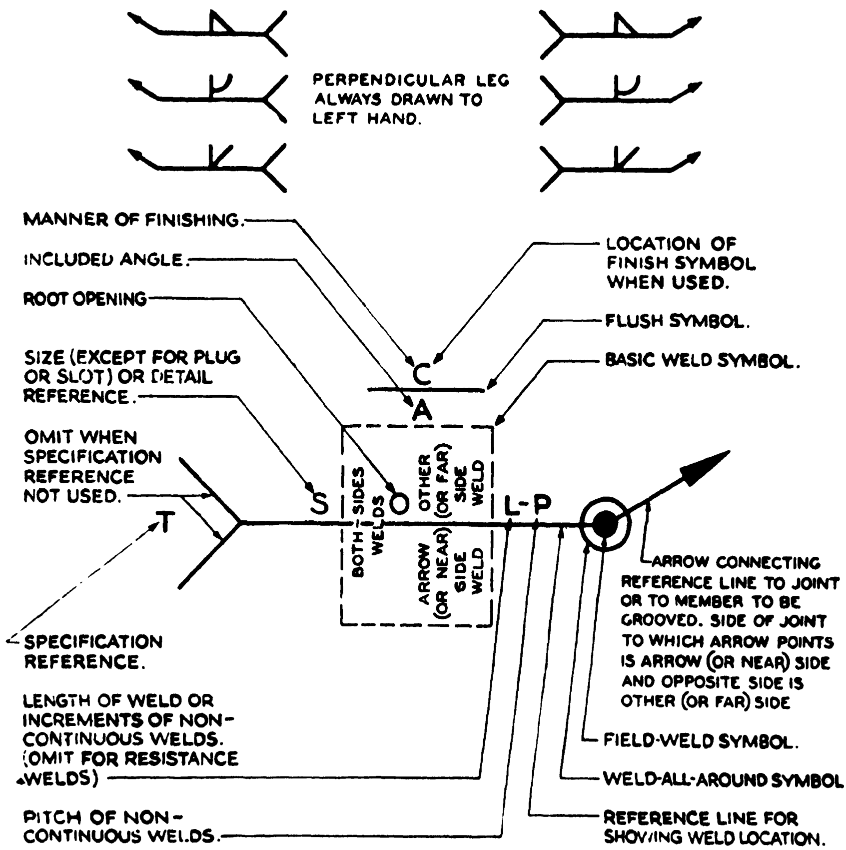
363. Welding Symbols and Instructions for Their Use

The American Welding Society symbols given herein are a development of the welding symbols in use here and abroad, and supersede the Society's former symbols which were published in bulletin form in 1929 and revised in February 1935, and September 1939. The symbols themselves given herein are the same as those which

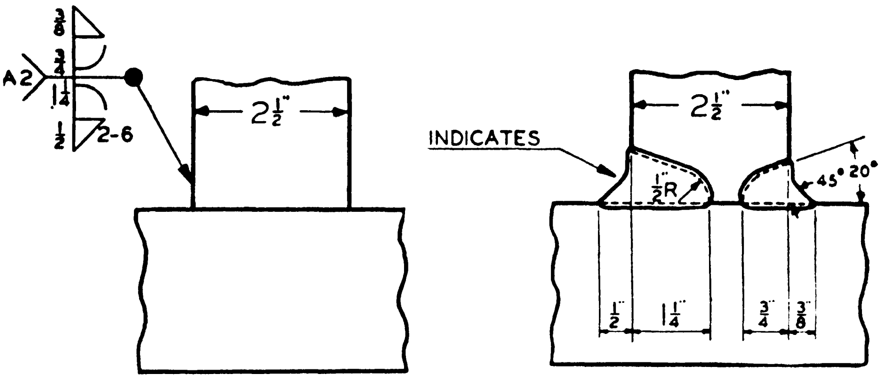


have been used heretofore but the method of using them has been improved and clarified.

These symbols provide the means of placing complete welding information on drawings. Even though the legends, numerical data and the instructions involve a considerable mass of material, nevertheless the successful use of the scheme depends so little on the memory that hardly more than one reading of the instructions is necessary to obtain a working understanding of the system. In practice many companies will probably need only a few of the symbols, and if they desire, can make up their own legends to suit themselves, selecting such parts of the scheme as fit their needs and



neglecting the others. If this is done universally, we shall all be speaking the same language even though some use but a few of the symbols contained herein.



SKETCH 1 SKETCH 2

Interpretation of Symbol:

Double-fillet-welded, partially-grooved, double-J, tee-joint with incomplete penetration. (Type of joint shown by drawing.) Grooves of standard proportions (which are, 1/2 in. R, 20° included angle, edges in contact before welding) 3/4 in. deep for other (or far) side weld and 1 1/4 in. deep for arrow (or near) side weld. 3/8 in. continuous other (or far) side fillet weld and 1/2 in. intermittent arrow (or near) side fillet weld with increments 2 in. long, spaced 6 in. center-to-center. All fillets standard 45° fillets. All welding done in field in accordance with welding specification number A2 (which requires that weld be made by manual D.C. shielded metal-arc process using high-grade, covered, mild steel electrode; that root be unchipped and welds unpeened but that joint be preheated before welding).

Instructions for Use of Welding Symbols

I General

(a) Do not use the word "weld" as a symbol on drawings.

(b) Symbols may or may not be made freehand as desired.

(c) Inch, degree and pound marks may or may not be used as desired.

(d) The symbol may be used without specification references or tails to designate the most commonly used specification when the following note appears on the drawing:
"Unless otherwise designated, all welds to be made in accordance with welding specification No. —."

(e) When specification references are used, place in tail of arrow.

(f) Symbols apply between abrupt changes in direction of joint or to extent of hatching or dimension lines (except where all-around symbol is used).

(g) Faces of welds assumed to have user's standard contours unless otherwise indicated.

(h) Faces of welds assumed not to be finished other than cleaned unless otherwise indicated.

(i) All except plug, spot, and projection welds assumed continuous unless otherwise indicated.

364. Standard Qualification Procedure

The American Welding Society (AWS) recognized the need for standardizing both the procedures for performing welds and the methods by which qualifications of welders may be determined. Accordingly the society issued "codes" and "Recommended Practices" for many years.

The latest release (1950) is known as American Welding Society Standard Qualifications Procedure.

Through the courtesy of the American Welding Society, we present in the following paragraphs necessary information for both Procedure Qualification Part I, and Operator Qualification Part II.

365. General Qualifications

These rules are intended to apply only to the manual application of the arc- and ges-welding processes, and to those ferrous metals which in their unwelded condition will meet the requirements of the guided bend test prescribed herein.

Each manufacturer or contractor shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding procedure to determine its suitability to ensure welds which will meet the required tests, but also of the welding operators to determine their ability to make sound welds under standardized test conditions.

It is assumed that the manufacturer or contractor has an organization familiar with the various welding codes and capable of designing, engineering and supervising welded construction.

Rules for the qualification of a welding procedure are given in Part I. Rules for qualifying operators follow in Part II.

PART I—PROCEDURE QUALIFICATIONS

366. Limitation of Variables

(*a*) The procedure of welding to be followed in construction shall be established and recorded by the manufacturer or contractor as a Procedure Specification, and in the investigation to qualify this procedure, the Procedure Specification shall be followed. Recommended forms for the Procedure Specification are given in the Appendix.

It is not necessary that these exact forms be used, but the information contained therein should be set forth in any alternate form which is adopted.

(*b*) If any changes are made in a procedure, the Procedure Specification shall be revised or amended to show these changes.

The changes set forth in the following schedule shall be considered essential changes and shall require requalification of the procedure or operator or both. Any change marked "P" or "PO" shall require requalification of the procedure; any changed marked "PO" or "O" shall require requalification of the operator.

P 1 A change in the specification of base metal to be welded from one "P" Number to another "P" Number. (See Table 5.)*

PO 2 A change in the specification of base metal to be welded from one "O" Number to another "O" Number. (See Table 5.)

PO 3 A change in filler metal from one American Welding Society Specification** to another Specification.

P 4 A change in filler metal from one American Welding Society Classification Number† to another American Welding Society Classification Number.

O 5 A change in filler metal from a bare or lightly coated electrode to a covered electrode, or vice versa, within any given American Welding Society specification for arc welding electrodes.‡

P 6 An increase in the diameter of the electrode or welding rod used, over that called for in the Procedure Specification.

P 7 A change of more than 15 per cent above or below the specified mean arc voltage and amperage for each size electrode used.

P 8 For a specified welding groove, a change of more than plus

* When any "P" group in Table 5 contains materials having specified minimum tensile strengths higher than the tensile strength obtained in the actual procedure qualification tension test, it may be desirable for governing codes to require procedure qualification using these higher tensile materials before they can be welded in actual construction.

** See American Welding Society filler metal specifications.

† For example: A change from an E6010 to an E6012 or E7010 electrode (Tentative Specifications for Iron and Steel Arc Welding Electrodes); or a change from a G60 to a G45 or G65 welding rod (Tentative Specifications for Iron and Steel Gas Welding Rods).

‡ For example: A change from an E6010 to an E4510 electrode requires requalification of the operator; a change from an E6010 to an E6020 or E6030 electrode *does not* require requalification of the operator (Tentative Specifications for Iron and Steel Arc Welding Electrodes).

or minus 25 per cent in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.

PO 9 A change in the position in which welding is done as defined in Articles 369 and 379.

O 10 In the case of vertical welds, a change from the progression specified for any pass from upward to downward or vice versa.

P 11 A decrease in the preheating temperature.

P 12 A change in the heat-treating temperature range or time range.

P 13 A change in the specified range of sizes of gas-welding tips.

P 14 A change of gas-welding flame from neutral to one with an excess of acetylene or vice versa.

O 15 A change from the "backhand" to the "forehand" method of welding. (Gas or carbon arc welding.)

P 16 A decrease in the number of layers used in gas welding.

P 17 A change in the type of welding groove. (Example, change from a V to a U shape.)

P 18 A change in the shape of any one type of welding groove involving:

(1) a decrease in the included angle of the welding groove, or a decrease in the width of the groove; or
(2) a decrease in the root opening of a welding groove; or
(3) an increase in the root face of a welding groove; or
(4) the addition or omission of a backing strip.

367. Types of Tests and Purposes

The types of tests outlined below are to determine the tensile strength, ductility and degree of soundness of welded joints made under a given Procedure Specification. The tests used are as follows:

(*a*) *For Groove Welds*

(1) Reduced-Section Tension Test (for Tensile Strength)
(2) Free-Bend Test (for Ductility)
(3) Root-Bend Test (for Soundness)
(4) Face-Bend Test (for Soundness)
(5) Side-Bend Test (for Soundness)

(*b*) *For Fillet Welds*

(1) Longitudinal or Transverse Shear Test (for Shear Strength)
(2) Free-Bend Test (for Ductility)
(3) Fillet-Weld-Soundness Test (for Soundness)

368. Base Material and Its Preparation

The base material and its preparation for welding shall comply with the Procedure Specification.* For all types of welded joints the length of the weld and the dimensions of the base material shall be such as to provide sufficient material for the test specimens called for hereinafter.

369. Position of Test Welds

All welds that will be encountered in actual construction, except groove welds in pipe, shall be classified as being (1) Flat, (2) Horizontal, (3) Vertical or (4) Overhead, in accordance with the definitions of welding positions given in Fig. 343 (*a*) and 343 (*b*). Groove welds in pipe shall be classified as (1) Horizontal Rolled, (2) Horizontal Fixed or (3) Vertical, in accordance with the definitions of pipe welding positions given in Fig. 343 (*a*). Each procedure shall be tested in the manner stated below for each position for which it is to be qualified.

(*a*) *Groove Welds in Plate*

In making the tests to qualify groove welds in plate, the test plates shall be welded in the following positions:

(1) *Flat Position*—The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side. (Illustrated in *Figure 363* (a).)
(2) *Horizontal Position*—The test plates shall be placed in an approximately vertical plane with the welding groove approximately horizontal. (Illustrated in *Figure 363* (b).)
(3) *Vertical Position*—The test plates shall be placed in an approximately vertical plane with the welding groove approximately vertical. (Illustrated in *Figure 363* (c).)

* To avoid misleading results it is desirable that the base material used in the qualification of a procedure contain amounts of carbon, manganese, chromium, molybdenum and other alloys approaching the maximum quantities of these elements which may be present in the materials that will be welded in actual construction.

(4) *Overhead Position*—The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the under side. (Illustrated in *Figure 363* (d).)

(b) *Groove Welds in Pipe*

In making the tests to qualify groove welds in pipe, the pipe shall be welded in the following positions:

(1) *Horizontal Rolled*—The pipe shall be placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane and the pipe shall be rolled during welding. (Illustrated in *Figure 363* (a).)
(2) *Horizontal Fixed*—The pipe shall be placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane and the pipe shall not be rolled or turned during welding. (Illustrated in *Figure 363* (e).)
(3) *Vertical*—The pipe shall be placed with its axis in an approximately vertical position with the welding groove in an approximately horizontal plane. (Illustrated in *Figure 363* (b).)

(c) *Fillet Welds*

In making the tests to qualify fillet welds in plate, the test plates shall be welded in the positions outlined below. (If fillet welds are to be made in pipe, they shall be qualified by tests made in plate unless other tests arespecifically provided for by a governing Code.)

(1) *Flat Position*—The test plates shall be so placed that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical. (See *Figure 344* (a).)
(2) *Horizontal Position*—The test plates shall be so placed that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface. (See *Figure 344* (b).)
(3) *Vertical Position*—Each fillet weld shall be made vertically. (See *Figure 344* (c).)
(4) *Overhead Position*—The test plates shall be so placed that each fillet weld is deposited on the under side of the horizontal surface and against the vertical surface. (See *Figure 344* (d).)

NOTE: The above arrangement of test plates refers only to the making of the fillet welds. The closing weld between fillet welds in the fillet-weld-soundness test may be made in any position.

370. Number of Test Welds Required

(a) *Groove Welds in Plate or Pipe*

For groove welds in material up to and including ¾ in. thick, one test weld shall be made in material ⅜ in. thick* for each procedure and position to be used in construction, except that if the construction involves welding of material over ¾ in. thick, a test weld shall be made in material of the maximum thickness* to be used in construction for each procedure and position, but which need not exceed 1 in.* If a test is made in the maximum or 1 in. thickness, no test need be made in the ⅜ in. thickness. In the case of pipe, the nominal diameter of the pipe used for the test weld shall not be less than 6 in.

(b) *Fillet Welds*

For fillet welds two longitudinal or two transverse shear test welds shall be made for each procedure and position to be used in construction. For each type of test weld, one shall be made with the maximum size single-pass fillet weld and one with the minimum size multiple-pass fillet weld that will be used in construction. In addition, one test weld for the free-bend and fillet-weld-soundness tests shall be made with the maximum size single-pass fillet weld (not over ⅜ in.) that will be used in construction, for each procedure and position to be used in construction.

371. Welding Procedure

The welding procedure shall comply in all respects with the Procedure Specification.

372. Test Specimens—Number, Type and Preparation

(a) *Groove Welds*

For groove welds in plate the method of preparing the specimens shall be in accordance with the figures referred to in Table 1 and the number of tests required shall be as given in the table. The test specimens shall be removed in the order given in *Figures 352* and *353*.

For groove welds in pipe the method of preparing the specimens shall be in accordance with the figures referred to in Table 2 and the number of tests required shall be as given in the table. The test specimens shall be removed in the order given in *Figures 357* and *358*.

* In the case of pipe, the wall thickness may vary + or −12½ per cent from that indicated.

TABLE 1—PROCEDURE QUALIFICATION TESTS FOR GROOVE WELDS IN PLATE

Maximum Thickness to Be Welded in Construction	Test Plate Thickness	Number and Type of Tests Required: Reduced-Section Tension. (See Fig. 348)	Free-Bend. (See Fig. 349)	Root-Bend. (See Fig. 350)	Face-Bend. (See Fig. 350)	Side-Bend. (See Fig. 351)
Up to and including ¾ in.	⅜ in.	2	2	2	2	..
Over ¾ in.	Maximum, but need not exceed 1 in.	2	2	..	..	4

TABLE 2—PROCEDURE QUALIFICATION TESTS FOR GROOVE WELDS IN PIPE

Maximum Thickness to Be Welded in Construction	Test Pipe Wall Thickness	Number and Type of Tests Required: Reduced-Section Tension. (See Fig. 354)	Free-Bend. (See Fig. 355)	Root-Bend. (See Fig. 356)	Face-Bend. (See Fig. 356)	Side-Bend. (See Fig. 351)
Up to and including ¾ in.	⅜ in.	2	2	2	2	..
Over ¾ in.	Maximum, but need not exceed 1 in.	2	2	..	..	4

(b) *Fillet Welds*

The longitudinal shear test specimens shall be welded as shown in *Figure 345* and prepared for testing as shown in *Figure 359.* The transverse shear test specimens shall be made as shown in *Figure 346.*

The test weld for the free-bend and soundness tests shall be made as shown in *Figure 347.* From the test weld there shall be taken two free-bend test specimens, which shall be prepared for testing as shown in *Figure 349,* and two fillet-weld-soundness test specimens as shown in *Figure 362.*

373. Method of Testing Specimens

(a) *Reduced-Section Tension Specimens*

Before testing, the least width and corresponding thickness of the reduced section shall be measured in inches. The specimen shall be

ruptured under tensile load and the maximum load in pounds shall be determined. The cross-sectional area shall be obtained as follows: cross-sectional area = width $\times$ thickness. The tensile strength in pounds per sq. in. shall be obtained by dividing the maximum load by the cross-sectional area.

(b) *Free-Bend Test Specimens*

The gage lines indicated in *Figure 349* shall be lightly scribed on the face of the weld. The gage length (distance between gage lines) shall be approximately 1/8 in. less than the width of the face of the weld, and shall be measured in inches to the nearest 0.01 in.

Each specimen may be bent initially by the use of a fixture complying with the requirements of *Figure 360*. The surface of the specimen containing the gage lines shall be directed toward the supports. The weld shall be at midspan of both the supports and the loading block. Alternatively, the initial bend may be made by holding each specimen in the jaws of a vise with one-third the length of the specimen projecting from the jaws, then bending the specimen away from the gage lines through an angle of from 30 to 45° by blows of a hammer. The other end of the specimen shall be bent in the same way. In order that the final bend shall be centered on the weld, the initial bends shall be symmetrical with respect to the weld, and both ends shall be bent through the same angle. The initial bend may also be started at the weld by placing the specimen in the guided-bend test jig shown in *Figure 361*.

Compressive forces shall be applied to the ends of the specimen, continuously decreasing the distance between the ends. (Any convenient means such as a vise or a testing machine may be used for the final bend.) When a crack or other open defect exceeding 1/16 in.* in any direction appears on the convex face of the specimen, the load shall immediately be removed. If no crack appears, the specimen shall be bent double. Cracks occurring on the corners of the specimen during testing shall not be considered.

The elongation shall be determined by measuring the minimum distance between the gage lines, along the convex surface of the weld, to the nearest 0.01 in. and subtracting the initial gage length. The per cent elongation shall be obtained by dividing the elongation

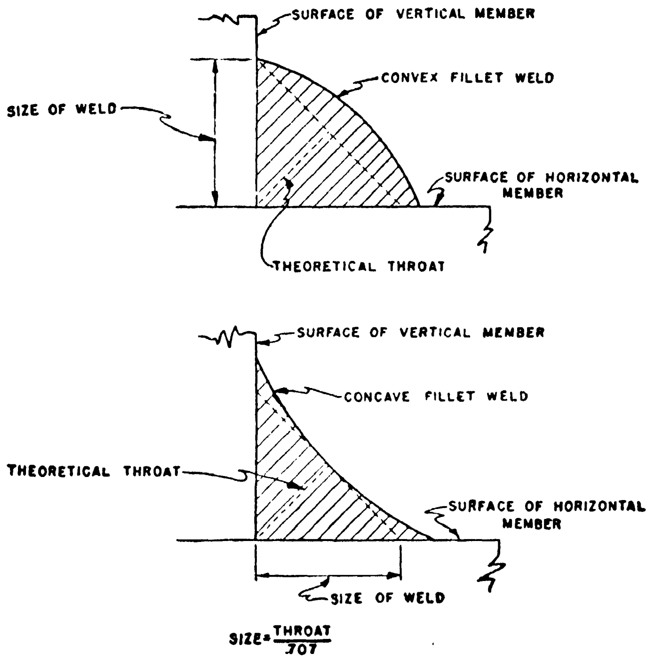
---

* See Note I Par. 374.

by the initial gage length and multiplying by 100.

(c) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Specimens*

Each specimen shall be bent in a jig having the contour shown in *Figure 361,* and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the male member with relation to the female member.



The size and theoretical throat dimension of a fillet weld shall be defined as illustrated. The size of a fillet weld is the leg length of the largest inscribed isosceles right triangle. The theoretical throat dimension may be obtained by multiplying the size of the fillet weld by 0.707.

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a $1/32$ in. diameter wire cannot be passed between the curved portion of the male member and the

specimen. The specimen shall then be removed from the jig.

(d) *Longitudinal and Transverse Shear Test Specimens*

Before testing, the length of the individual welds shall be measured in inches and if any weld varies by more than $\frac{1}{16}$ in. from the length specified in *Figures 346* and *359*, then the length of each weld and its location shall be recorded. The average size of the fillet welds shall also be recorded. The specimen shall be ruptured under tensile load and the maximum load in pounds shall be determined. The shearing strength of the welds in pounds per linear inch shall be obtained by dividing the maximum force by the sum of the lengths of the welds which ruptured. The shearing strength of the welds in pounds per sq. in. shall be obtained by dividing the shearing strength in pounds per linear inch by the average theoretical throat dimension of the welds in inches.

374. Test Results Required

The requirements for the test results shall be as follows:

(a) *Reduced-Section Tension Test*

The tensile strength shall be not less than 100 per cent of the minimum of the specified tensile range of the base material used. (See Notes I and III.)

(b) *Free-Bend Test*

The elongation shall be not less than 30 per cent for stress-relieved welds nor less than 25 per cent for non-stress-relieved welds. (See Notes I and III.)

(c) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Tests*

The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect is present after the bending, exceeding $\frac{1}{8}$ in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered. (See Notes I and III.)

(d) *Longitudinal or Transverse Shear Test*

For the longitudinal shear test specimen the shearing strength of the welds in pounds per square inch shall be not less than $\frac{2}{3}$ of the minimum of the specified tensile range of the base material. For

the transverse shear test specimen the shearing strength of the welds in pounds per sq. in. shall be not less than 7/8 of the minimum of the specified tensile range of the base material. (See Notes I, II and III.)

NOTE I: These values as set forth shall apply where no Code is in effect, or where an agreement to use other values has not been made between the purchaser and vendor.

NOTE II: These values are applicable only to low carbon, non-alloy steels. For other materials, the values shall be a matter of agreement between the purchaser and vendor.

NOTE III: The test results specified are not likely to be attained with the metal arc process when using bare or lightly coated electrodes. For such processes it is recommended that the governing Code adopt the following requirements for the test results:

a. Reduced-Section Tension Test—The tensile strength shall be not less than 85 per cent of the minimum of the specified tensile range of the base material used.

b. Free-Bend Test—The elongation shall be not less than 10 per cent.

c. Root-, Face-, Side-Bend and Fillet-Weld-Soundness Tests—The specimen shall be considered as having passed if (1) no crack or other open defect exceeding 1/8 in. measured in any direction is present in the weld metal or between the weld and base material after the bending, or (2) the specimen has cracked or fractured and the fractured surface shows complete penetration through the entire thickness of the weld, and absence of slag inclusions and porosity to the extent that there are no gas pockets or slag inclusions exceeding 1/16 in. in greatest dimension and the sum of the greatest dimension of all such defects in any square inch of weld metal area does not exceed 3/8 in. (If necessary, the specimen shall be broken apart to permit examination of the fracture.)

d. Longitudinal or Transverse Shear Test—For the longitudinal shear test specimen the shearing strength of the welds in pounds per square inch shall be not less than 2/3 of the minimum of the specified tensile range of the base material. For the transverse shear test specimen the shearing strength of the welds in pounds per sq. in. shall be not less than 7/8 of the minimum of specified tensile range of the base material.

375. Records

Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

PART II—OPERATOR QUALIFICATION

376. Limitation of Variables

For the qualification of an operator the following rules shall apply. If certain changes are made in a Procedure Specification, operator requalification may be required in accordance with Par. 366 (b).

377. Types of Tests Required

The qualification tests described herein are specially devised tests to determine the operator's ability to produce sound welds, and may or may not conform in every detail to the requirements of the Procedure Specification. It is not intended that the practices required in the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the Procedure Specification.

The tests used for operator qualification are as follows:

(a) *For Groove Welds*

(1) Root-Bend Test
(2) Face-Bend Test
(3) Side-Bend Test

(b) *For Fillet Welds*

Fillet-Weld-Soundness Test

378. Base Material and Its Preparation

(a) The base material shall comply with the specification for one of the materials listed in the Procedure Specification. For all types of welded joints the length of the weld and the dimensions of the base material shall be such as to provide sufficient material for the test specimens called for hereinafter.

(b) For groove welds in plate or pipe where the thickness of the material for the tests as specified in Par. 380 (a) is $3/8$ in., the preparation of the base material for welding shall be for a single-V groove butt joint meeting the requirements of *Figure 364*, except that in the case of oxyacetylene welding the joint preparation may be in accordance with *Figure 366*.

(c) For groove welds in plate or pipe where the thickness of the material as specified in Par. 380 (a) exceeds $3/8$ in., the preparation of the base material for welding shall be for a single-V groove butt joint meeting the requirements of *Figure 365*, except that in the case of oxyacetylene welding the joint preparation may be in accordance with *Figure 367*.

(d) For fillet welds the preparation of the base material for welding shall be as shown in *Figure 368*. Pipe with a nominal diameter of not less than 6 in. may be used in lieu of plate.

379. Position of Test Welds

(a) *Groove Welds*

For the purpose of determining the ability of an operator to make groove welds in various positions in plate or pipe the following positions for test are required.

Test Position 1G

Plates placed in an approximately horizontal plane and the weld metal deposited from the upper side, or a pipe placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane, the pipe being rolled while the weld is deposited within the top quadrant and from the outside of the pipe. (See *Figure 363* (a).) This test made either in plate or pipe will qualify the operator for flat position welds in plate and for pipe in the horizontal rolled position. (See *Figure 342.*)

Test Position 2G

Plates placed in an approximately vertical plane with the welding groove in an approximately horizontal plane, or a pipe placed with its axis in an approximately vertical plane with the welding groove in an approximately horizontal plane. (See *Figure 363* (b).) This test made either in plate or pipe will qualify the operator for flat and horizontal welds in plate and for pipe in the horizontal rolled and vertical fixed positions. (See *Figure 342.*)

Test Position 3G

Plates placed in an approximately vertical plane with the welding groove approximately vertical. (See *Figure 363* (c).) This test will qualify the operator for flat and vertical welds in plate and for pipe in the horizontal rolled position. (See *Figure 342.*)

Test Position 4G

Plates placed in an approximately horizontal plane and the weld metal deposited from the under side. (See *Figure 363* (d).) This test will qualify the operator for flat, and overhead welds in plate and for pipe in the horizontal rolled position.

Test Position 5G

A pipe or plate box placed with its axis in an approximately horizontal plane with the welding groove in an approximately

vertical plane. The pipe or box shall not be rolled or turned during welding, thus requiring the operator to deposit weld metal from the flat, vertical and overhead positions. (See *Figure 363* (e).) This test made either in pipe or a plate box will qualify the operator for welds made in plate in the flat, vertical and overhead positions, and in pipe in the horizontal rolled and horizontal fixed positions. (See *Figure 342.*)

If a welding operator is tested in Position 2G he need not be tested in Position 1G. If a welding operator is tested in Position 3G he need not be tested in Position 1G. If a welding operator is tested in Position 4G he need not be tested in Position 1G. If a welding operator is tested in Position 5G he need not be tested in Position 1G, 3G or 4G.

(b) *Fillet Welds*

For the purpose of determining the ability of an operator to make fillet welds in various positions the following positions for test are required:

Test Position 1F

Plates placed in such position that each weld is deposited with its axis approximately horizontal and with its throat approximately vertical. (See *Figure 369* (a).) This test will qualify the operator for flat fillet welds. (See *Figure 343.*)

Test Position 2F

Plates or pipe placed in such position that each weld is deposited on the upper side of the horizontal surface and against the vertical surface. (See *Figure 369* (b).) This test, made either in plate or pipe, will qualify the operator for flat and horizontal fillet welds. (See *Figure 343.*)

Test Position 3F

Plates or pipe placed in such position that each weld is made vertically. (See *Figure 369* (c).) This test, made either in plate or pipe, will qualify the operator for flat, horizontal and vertical fillet welds. (See *Figure 343.*)

Test Position 4F

Plates or pipe placed in such position that each weld is depos-

ited on the under side of the horizontal surface and against the vertical surface. (See *Figure 369* (d).) This test, made either in plate or pipe, will qualify the operator for flat, horizontal and overhead fillet welds. (See *Figure 343*.)

NOTE: The above arrangement of test plates or pipe refers only to the making of the fillet weld. The closing weld between fillet welds in the fillet-weld-soundness test may be made in any position. See *Fig. 369* (e).

If a welding operator is tested in Position 2F he need not be tested in Position 1F. If a welding operator is tested in Position 3F he need not be tested in Position 1F or 2F. If a welding operator is tested in Position 4F he need not be tested in Position 1F or 2F.

380. Number of Test Welds Required

(a) *Groove Welds in Plate and Pipe*

For groove welds in material up to and including ¾ in. thick* one test weld as shown in *Figure 364* (*Figure 366* may be used for oxyacetylene welding) shall be made in material ⅜ in. thick for each position for which the operator is to be qualified as defined by Par. 379 (a), except that if the construction involves welding of material over ¾ in. thick* one test weld as shown in *Figure 365* (*Figure 367* may be used for oxyacetylene welding) shall be made for each such position in material of the maximum thickness to be used in construction, but the thickness of the material for the test weld need not exceed 1 in. If a test weld is made in the maximum or 1-in. thickness, no test weld need be made in the ⅜-in. thickness. In the case of pipe, the nominal diameter of the pipe used for the test weld shall not be less than 6 in.

(b) *Fillet Welds*

For fillet welds one test weld as shown in *Figure 368* shall be made for each position for which the operator is to be qualified, as defined by Par. 379 (b).

* Whereas reference has been made above to the test welds being made in material of a given thickness, it is the intent of these rules that if an operator is qualified to weld in a single groove of a given depth, he is also considered as being qualified for welding double-groove butt joints wherein the depth of the groove from either side does not exceed the depth of the single groove for which he has been qualified.

381. Welding Procedure

The operator shall follow the welding procedure specified by the Procedure Specification except that if the form of the test joint differs from the forms of joint as shown in the Procedure Specification to such a degree that it is necessary, in welding the test joint, to change the electrode or welding rod diameters or the number and arrangement of passes from that called for in the Procedure Specification, such changes shall be permissible.

382. Test Specimens—Number, Type and Preparation

(a) *Groove Welds*

For groove welds in plate the method of preparing the specimens shall be in accordance with the figures referred to in Table 3 and the number of tests required shall be as given in the table.

For groove welds in pipe the method of preparing the specimens shall be in accordance with the figures referred to in Table 4 and the number of tests required shall be as given in the table.

If the test weld is made in pipe in Position 1G or 2G, the specimens shall be removed approximately 90° from each other. If the test weld is made in Position 5G, using either a pipe or a plate box, a specimen shall be removed from the top, the bottom and each of the two sides of the test weld; and, if the weld is made in ⅜-in.-thick material, the specimen from the top and one side shall be tested with the face of the weld in tension, and the specimen from the bottom and from the other side shall be tested with the root of the weld in tension.

(b) *Fillet Welds*

Two test specimens shall be removed from each test weld and prepared for testing as shown in *Figure 362.*

383. Method of Testing Specimens

(a) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Specimens*

Each specimen shall be bent in a jig substantially in accordance with *Figure 361.* Any convenient means may be used for moving the male member with relation to the female member.

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a 1/32-in. diameter wire cannot be passed between the curved portion of the male member and the specimen. The specimen shall then be removed from the jig.

TABLE 3—OPERATOR QUALIFICATION TESTS FOR GROOVE WELDS IN PLATE

Maximum Thickness for Which Operator Is to Be Qualified	Thickness of Material for Test Weld	Number and Type of Tests Required Root-Bend. (See Fig. 350)	Face-Bend (See Fig. 350)	Side-Bend. (See Fig. 351)
Up to and including 3/4 in.	3/8 in.	1	1	..
Over 3/4 in.	Maximum, but need not exceed 1 in.	..	..	2

TABLE 4—OPERATOR QUALIFICATION TESTS FOR GROOVE WELDS IN PIPE

Maximum Thickness for Which Operator Is to Be Qualified	Thickness of Material for Test Weld	Number and Type of Tests Required Root-Bend. (See Fig. 356)	Face-Bend. (See Fig. 356)	Side-Bend. (See Fig. 351)
Up to and including 3/4 in.	3/8 in.	2	2	..
Over 3/4 in.	Maximum, but need not exceed 1 in.	..	..	4

384. Test Results Required

(a) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Tests*

The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect is present after the bending, exceeding 1/8 in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered. (See Notes I and II.)

NOTE I: These values as set forth shall apply where no Code is in effect, or where an agreement to use other values has not been made between the purchaser and vendor.

NOTE II: The test results specified are not likely to be attained with the metal arc process when using bare or lightly coated electrodes. For such processes it is recommended that the governing Code adopt the following requirements for the test results:

The specimen shall be considered as having passed if (1) no crack or other open defect exceeding ⅛ in. measured in any direction is present in the weld metal or between the weld and base material after the bending, or (2) the specimen has cracked or fractured and the fractured surface shows complete penetration through the entire thickness of the weld, and absence of slag inclusions and porosity to the extent that there are no gas pockets or slag inclusions exceeding $1/16$ in. in greatest dimension and the sum of the greatest dimension of all such defects in any square inch of weld metal area does not exceed ⅜ in. (If necessary, the specimen shall be broken apart to permit examination of the fracture.)

385. Retests

In case an operator fails to meet the requirements of one or more test welds a retest may be allowed under the following conditions:

(a) An immediate retest may be made which shall consist of two test welds of each type on which he failed, all of which shall meet all the requirements specified for such welds.

(b) A retest may be made provided there is evidence that the operator has had further training or practice. In this case a complete retest shall be made.

386. Period of Effectiveness

The operator qualification tests herein specified shall be considered as remaining in effect indefinitely unless (1) the welding operator is not engaged in a given process of welding (i.e., arc or gas) for a period of three months or more;* or unless (2) there is some specific reason to question an operator's ability. In case (1) above the requalification test need be made only in the ⅜ in. thickness.

387. Records

Copies of the record for each qualified welding operator shall be kept by the manufacturer or contractor, and shall be available to those authorized to examine them.

---

* The intent of this statement is as follows:

An operator who has been qualified for metal arc welding under any given Procedure Specification is not required to requalify for that Procedure unless he has done no metal arc welding for a period of three months or more. In a similar manner the qualification of an operator for gas welding or for carbon arc welding is not considered as having expired unless he has done no gas welding or carbon arc welding, as the case may be, for a period of three months or more.

TABLE 5—GROUPING OF MATERIALS FOR PROCEDURE AND OPERATOR QUALIFICATION *

"P" Number 1—"O" Number 1

Materials in this group shall not have a carbon content exceeding 0.30 per cent, a manganese content exceeding 1.10 per cent, or a silicon content exceeding 0.50 per cent, as determined by ladle analysis. In addition, the carbon content by percentage shall not exceed the value $0.55 - \left(\frac{Mn + Si}{4}\right)$, where Mn is the percentage of manganese and Si is the percentage of silicon.

A. S. T. M. Spec. No.		Name
A-7		Steel for Bridges and Buildings
A-10		Mild Steel Plates
A-30		Boiler and Firebox Steel for Locomotives
A-53		Welded and Seamless Steel Pipe
A-70		Carbon-Steel Plates for Stationary Boilers, etc.
A-78		Low Tensile Strength Carbon Steel Plates of Structural Quality for Welding
A-83		Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes
A-87	Grade A1	Carbon-Steel and Alloy-Steel Castings for Railroads
	Grade A2	Carbon-Steel and Alloy-Steel Castings for Railroads
A-89		Low Tensile Strength Carbon-Steel Plates of Flange and Firebox Quality
A-105		Forged or Rolled Steel Pipe Flanges for High-Temperature Service
A-106	Grade A	Lap-Welded and Seamless Steel Pipe for High-Temperature Service
	Grade OH	Lap-Welded and Seamless Steel Pipe for High-Temperature Service
A-107	Grade 1	Commercial Quality Hot-Rolled Bar Steels
	Grade 2	Commercial Quality Hot-Rolled Bar Steels
	Grade 3	Commercial Quality Hot-Rolled Bar Steels
	Grade 4	Commercial Quality Hot-Rolled Bar Steels
	Grade 5	Commercial Quality Hot-Rolled Bar Steels
	Grade 17	Commercial Quality Hot-Rolled Bar Steels
A-113		Structural Steel for Locomotives and Cars
A-120		Black Welded and Seamless Steel Pipe, etc. (Galvanized pipe not included)
A-129		Open-Hearth Iron Plates of Flange Quality
A-131		Structural Steel for Ships
A-134		Electric-Fusion-Welded Steel Pipe (Size 30 in. and over)
A-135		Electric-Resistance-Welded Steel Pipe
A-136		Forge-Welded Steel Pipe
A-139		Electric-Fusion-Welded Steel Pipe (8 in. to but not including 30 in. diam.)
A-155		Electric-Fusion-Welded Steel Pipe for High-Temperature and High-Pressure Service
A-178	Grade A	Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
	Grade B	Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
A-181		Forged or Rolled Steel Pipe Flanges for General Service

* Steels not included in the table require separate procedure and operator qualification except in the case of the so-called low-alloy, high-strength steels. In the latter group of steels separate procedure qualification is required for each change in brand or analysis but "O" Number 1 applies in all cases.

"P" Number 1—"O" Number 1—(*Continued*)

A-192		Seamless Steel Boiler Tubes for High-Pressure Service
A-201		Carbon-Silicon Steel Plates of Ordinary Tensile Ranges
A-215-39T	Grade N-1-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade A-1-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade A-2-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade A-3-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
A-216-40T	Grade WCA	Carbon-Steel Castings Suitable for Fusion Welding, etc. (to 850° F.)
A-235-40T	Grade A	Carbon-Steel Forgings for General Industrial Use
	Grade B	Carbon-Steel Forgings for General Industrial Use
	Grade C	Carbon-Steel Forgings for General Industrial Use
A-236-40T	Grade A	Carbon-Steel Forgings for Locomotives and Cars

"P" Number 2—"O" Number 1

A-42	Wrought-Iron Plates
A-72	Welded Wrought-Iron Pipe
A-73	Wrought-Iron Rolled or Forged Blooms and Forgings
A-162	Uncoated Wrought-Iron Sheets
A-207	Rolled Wrought-Iron Shapes and Bars

"P" Number 3—"O" Number 1

Materials in this group shall not have a carbon content exceeding 0.35 per cent, a manganese content exceeding 1.50 per cent, or a silicon content exceeding 0.50 per cent, as determined by ladle analysis. In addition, the carbon content by percentage shall not exceed the value $0.65 - \left(\frac{Mn + Si}{4}\right)$, where Mnis the percentage of manganese and Si is the percentage of silicon.

(Experience has indicated that it is advisable to preheat up to 350° F. when welding the materials included in this group.)

A-7		Steel for Bridges and Buildings
A-30		Boiler and Firebox Steel for Locomotives
A-70		Carbon-Steel Plates for Stationary Boilers, etc.
A-87	Grade B	Carbon-Steel and Alloy-Steel Castings for Railroads
A-95		Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service
A-105		Forged or Rolled Steel Pipe Flanges for High-Temperature Service
A-106	Grade B	Lap-Welded and Seamless Steel Pipe for High-Temperature Service
A-107	Grade 6	Commercial Quality Hot-Rolled Bar Steels
	Grade 7	Commercial Quality Hot-Rolled Bar Steels
A-131		Structural Steel for Ships
A-178	Grade C	Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
A-181		Forged and Rolled Steel Pipe Flanges for General Service
A-201		Carbon-Silicon Steel Plates of Ordinary Tensile Ranges, etc.

"P" Number 3—"O" Number 1—(Continued)

A-210		Medium-Carbon Seamless Steel Boiler and Superheater Tubes
A-212		High-Tensile Strength Carbon-Silicon Steel Plates, etc.
A-215-39T	Grade N-2-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade BW	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade B-1-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade B-2-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
A-216-40T	Grade WCB	Carbon-Steel Castings Suitable for Fusion Welding, etc. (to 850° F.)
A-235-40T	Grade C1	Carbon-Steel Forgings for General Industrial Use
	Grade D	Carbon-Steel Forgings for General Industrial Use
	Grade E	Carbon-Steel Forgings for General Industrial Use
A-236-40T	Grade B	Carbon-Steel Forgings for Locomotives and Cars
	Grade C	Carbon-Steel Forgings for Locomotives and Cars
	Grade D	Carbon-Steel Forgings for Locomotives and Cars

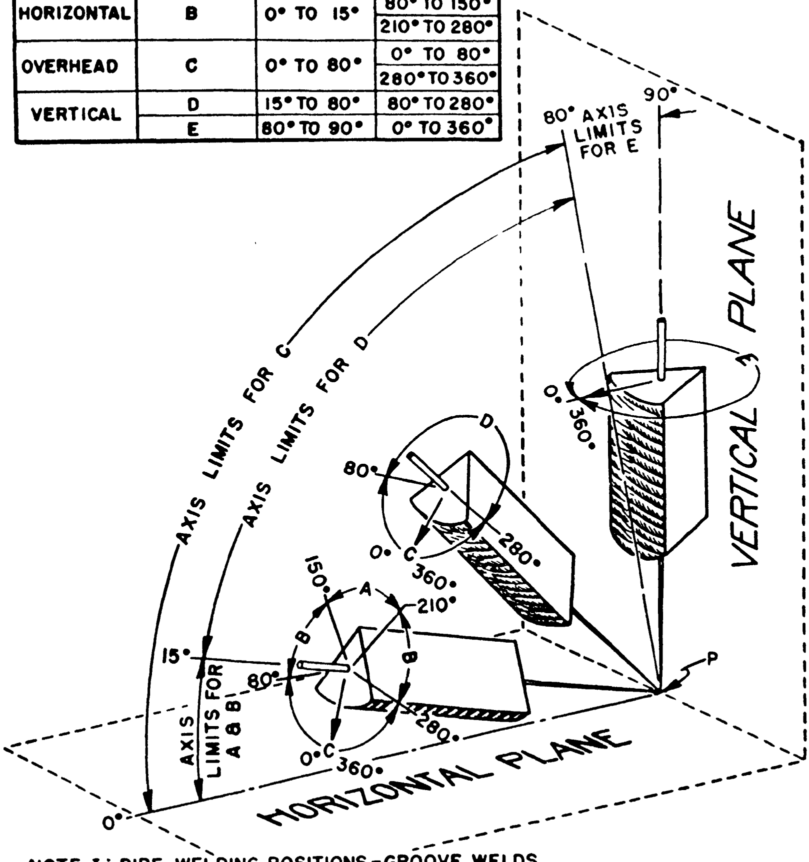
"P" Number 4—"O" Number 1

The carbon content by ladle analysis shall not exceed 0.28 per cent.

A-182	Grade F1	Forged or Rolled Alloy-Steel Pipe Flanges, etc. (from 750–1100° F.)
A-202	Grade A	Cr-Mn-Si Alloy-Steel Plates for Boilers, etc.
A-203	Grade A	Low-Carbon Nickel-Steel Plates for Boilers, etc.
	Grade B	Low-Carbon Nickel-Steel Plates for Boilers, etc.
A-204	Grade A	Molybdenum-Steel Plates for Boilers, etc.
	Grade B	Molybdenum-Steel Plates for Boilers, etc.
	Grade C	Molybdenum-Steel Plates for Boilers, etc.
A-206-40T		Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures of 750–1000° F.
A-209-40T		Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
A-217	Grade WC1	Alloy-Steel Castings Suitable for Fusion Welding, etc. (750–1100° F.)
	Grade WC2	Alloy-Steel Castings Suitable for Fusion Welding, etc. (750–1100° F.)
A-225		Manganese-Vanadium Steel Plates for Boilers, etc.

TABULATION OF POSITIONS OF GROOVE WELDS

POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° TO 15°	150° TO 210°
HORIZONTAL	B	0° TO 15°	80° TO 150°
			210° TO 280°
OVERHEAD	C	0° TO 80°	0° TO 80°
			280° TO 360°
VERTICAL	D	15° TO 80°	80° TO 280°
	E	80° TO 90°	0° TO 360°



NOTE I: PIPE WELDING POSITIONS-GROOVE WELDS

FOR GROOVE WELDS IN PIPE THE FOLLOWING DEFINITIONS SHALL APPLY.

HORIZONTAL FIXED POSITION: WHEN THE AXIS OF THE PIPE DOES NOT DEVIATE BY MORE THAN 30° FROM THE HORIZONTAL PLANE AND THE PIPE IS NOT ROTATED DURING WELDING.

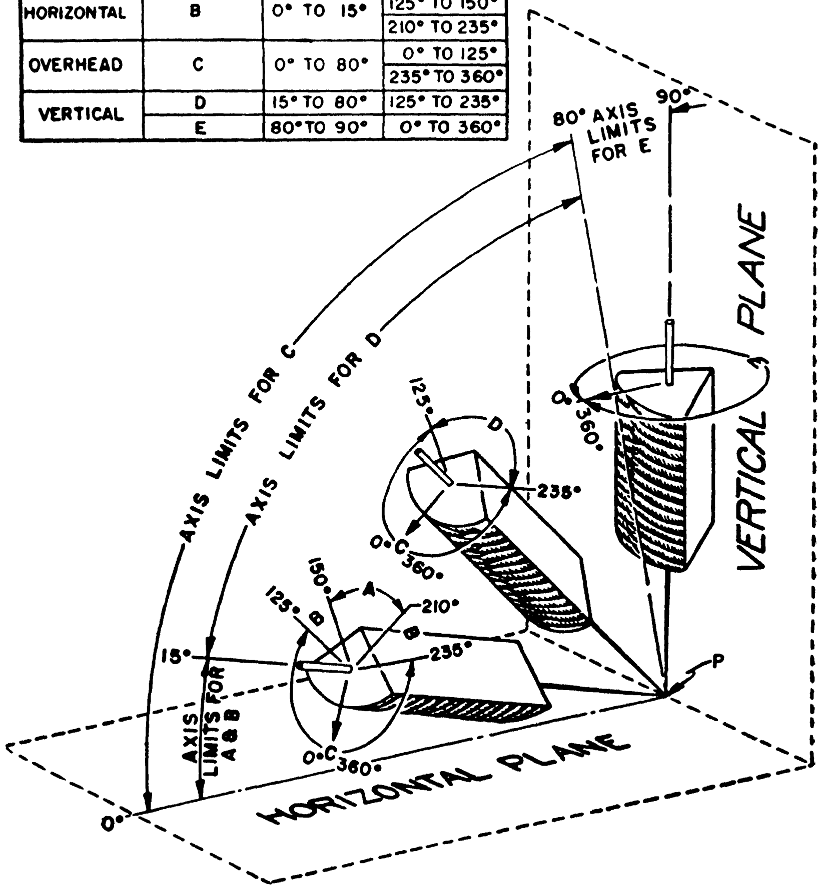
HORIZONTAL ROLLED POSITION: WHEN THE AXIS OF THE PIPE DOES NOT DEVIATE BY MORE THAN 30° FROM THE HORIZONTAL PLANE, THE PIPE IS ROTATED DURING WELDING, AND THE WELD METAL IS DEPOSITED WITHIN AN ARC NOT TO EXCEED 15° ON EITHER SIDE OF A VERTICAL PLANE PASSING THROUGH THE AXIS OF THE PIPE.

VERTICAL POSITION: WHEN THE AXIS OF THE PIPE DOES NOT DEVIATE BY MORE THAN 10° FROM THE VERTICAL POSITION (THE PIPE MAY OR MAY NOT BE ROTATED DURING WELDING.)*

*POSITIONS IN WHICH THE AXIS OF THE PIPE DEVIATES BY MORE THAN 10° AND LESS THAN 60° FROM THE VERTICAL SHALL BE CONSIDERED INTERMEDIATE, AND SHALL REQUIRE THE PROCEDURE AND OPERATOR TO BE QUALIFIED IN BOTH THE HORIZONTAL FIXED AND THE VERTICAL POSITIONS.

Figure 342. Identification of Positions of Groove Welds

TABULATION OF POSITIONS OF FILLET WELDS			
POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° TO 15°	150° TO 210°
HORIZONTAL	B	0° TO 15°	125° TO 150°
			210° TO 235°
OVERHEAD	C	0° TO 80°	0° TO 125°
			235° TO 360°
VERTICAL	D	15° TO 80°	125° TO 235°
	E	80° TO 90°	0° TO 360°



NOTE II:

THE HORIZONTAL REFERENCE PLANE IS TAKEN TO LIE ALWAYS BELOW THE WELD UNDER CONSIDERATION.

INCLINATION OF AXIS IS MEASURED FROM THE HORIZONTAL REFERENCE PLANE TOWARD THE VERTICAL.

ANGLE OF ROTATION OF FACE IS MEASURED FROM A LINE PERPENDICULAR TO THE AXIS OF THE WELD AND LYING IN A VERTICAL PLANE CONTAINING THIS AXIS. THE REFERENCE POSITION (0°) OF ROTATION OF THE FACE INVARIABLY POINTS IN THE DIRECTION OPPOSITE TO THAT IN WHICH THE AXIS ANGLE INCREASES. THE ANGLE OF ROTATION OF THE FACE OF WELD IS MEASURED IN A CLOCKWISE DIRECTION FROM THIS REFERENCE POSITION (0°) WHEN LOOKING AT POINT P.

Figure 343. Identification of Positions for Fillet Welds

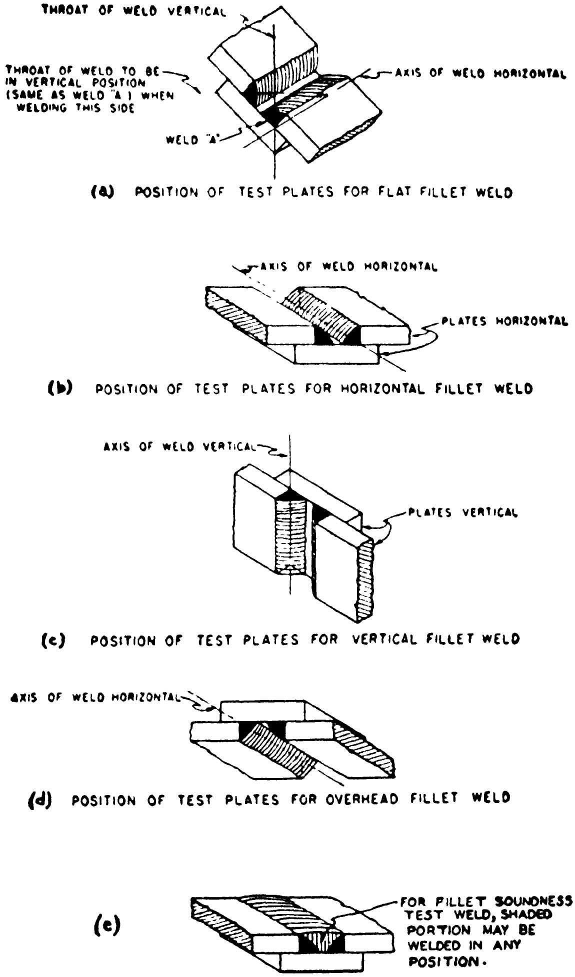
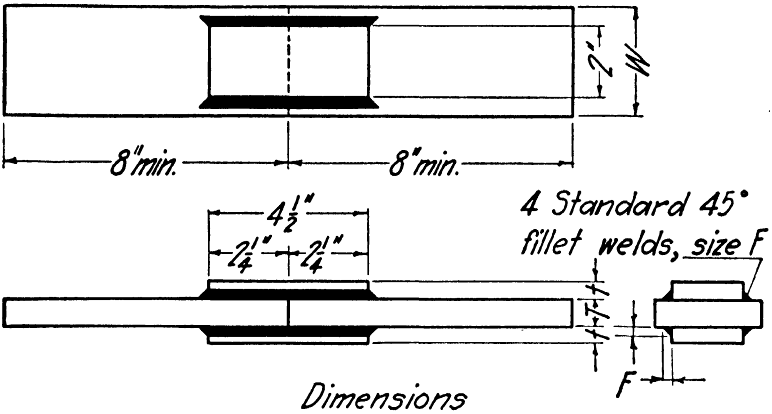


Figure 344. Position of Test Plates for Fillet Welds



Dimensions

Size of weld F, in.	1/8	1/4	3/8	1/2
Thickness t, in., min	3/8	1/2	3/4	1
Thickness T, in.	3/8	3/4	1	1¼
Width W, in.	3	3	3	3½

Figure 345. Longitudinal Fillet Weld Shearing Specimen after Welding all necessary specimen dimensions are indicated

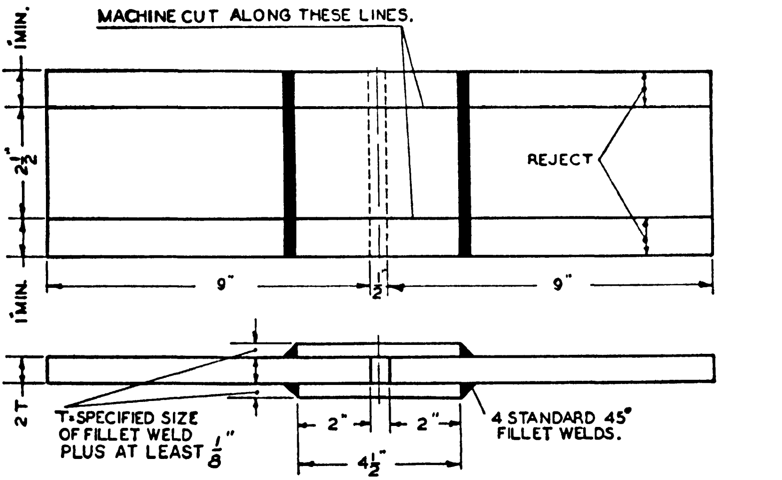


Figure 346. Transverse Fillet Weld Shearing Specimen after welding. Instructions for preparation (machining) the samples are indicated

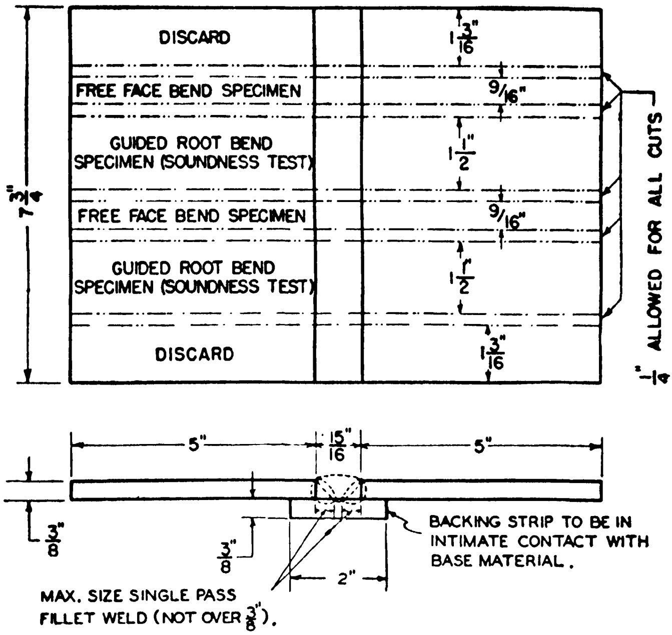


Figure 347. Test Weld for Free-bend and Soundness Tests. It should be noted that this sample must be cut into six pieces. Four of the pieces are used for test purposes

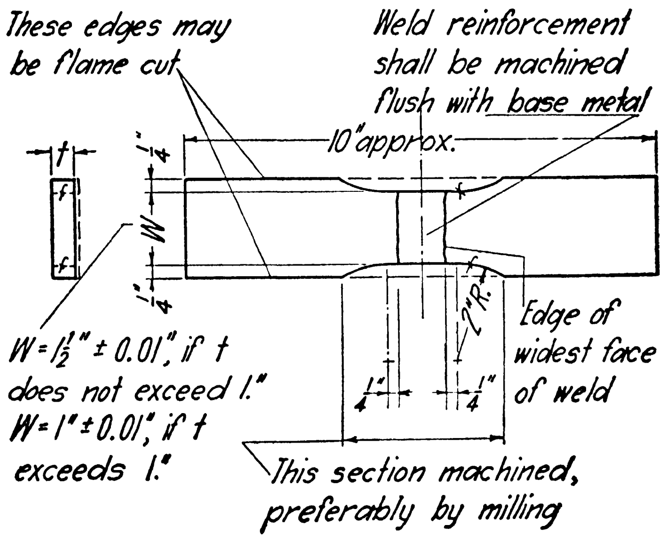
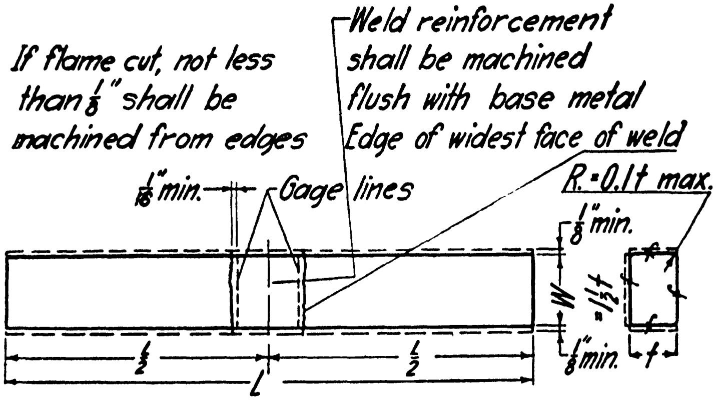


Figure 348. Reduced Section Tension Specimen (Plate). Dimensions of the required tension test specimen are indicated for any thickness metal

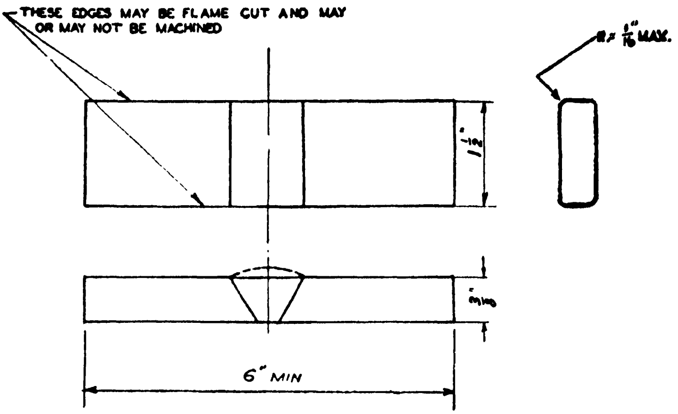


Dimensions

t, in.	3/8	3/4	1	1 1/4	1 1/2	2	2 1/2
W, in.	9/16	1 1/8	1 1/2	1 7/8	2 1/4	3	3 3/4
L min, in.	8	11	12	13 1/2	15	18	21
B*min, in.	1 1/4	2	2	2	2	2	3

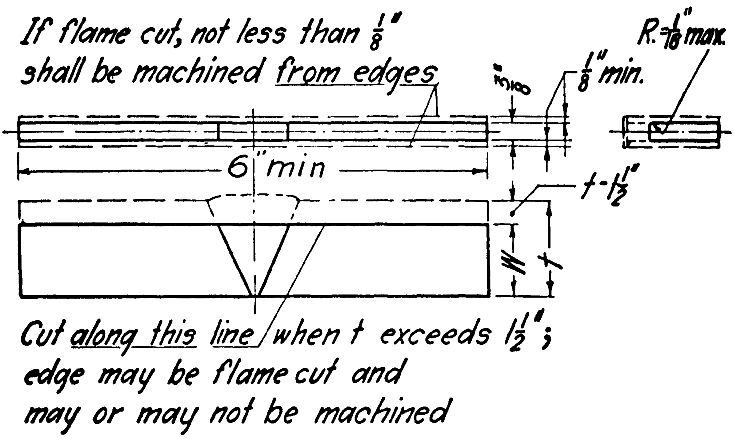
*SEE FIG. 360
NOTE 1: THE LENGTH L IS SUGGESTIVE ONLY, NOT MANDATORY.
NOTE 2: IF DESIRED, THE EDGES OF THE SPECIMEN MAY BE PREPARED BY MACHINE FLAME CUTTING, FOLLOWED BY ROUNDING OF THE CORNERS WITH A FILE, THOUGH THIS MAY BE A MORE SEVERE TEST.

Figure 349. Free-Bend Specimen (Plate). The table indicates the required dimensions for various plate thicknesses



NOTE:
WELD REINFORCEMENT AND BACKING STRIP, IF ANY, SHALL BE REMOVED FLUSH WITH THE SURFACE OF THE SPECIMEN. IF A RECESSED STRIP IS USED THIS SURFACE OF THE SPECIMEN MAY BE MACHINED TO A DEPTH NOT EXCEEDING THE DEPTH OF THE RECESS TO REMOVE THE STRIP, EXCEPT THAT IN SUCH CASES THE THICKNESS OF THE FINISHED SPECIMEN SHALL BE THAT SPECIFIED ABOVE.

Figure 350. Face and Root-Bend Specimens (Plate)



t, in.	W, in.
¾" to 1½"	t
> 1½"	1½"

Figure 351. Side-Bend Specimen

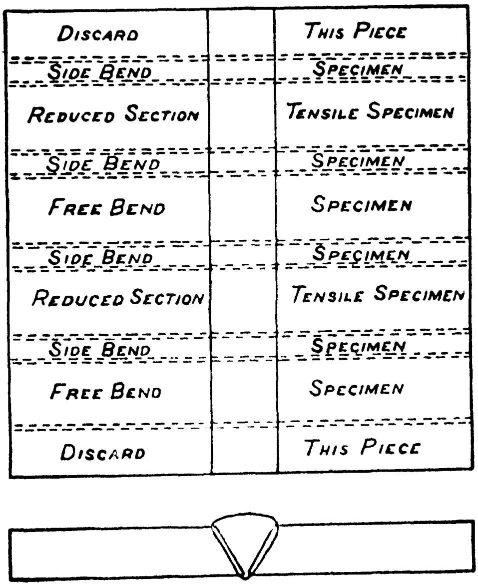


Figure 352. Order of Removal of Test Specimens from Welded Test Plate. (For plate over ¾" thick). The various test specimens should be cut from the sample as indicated

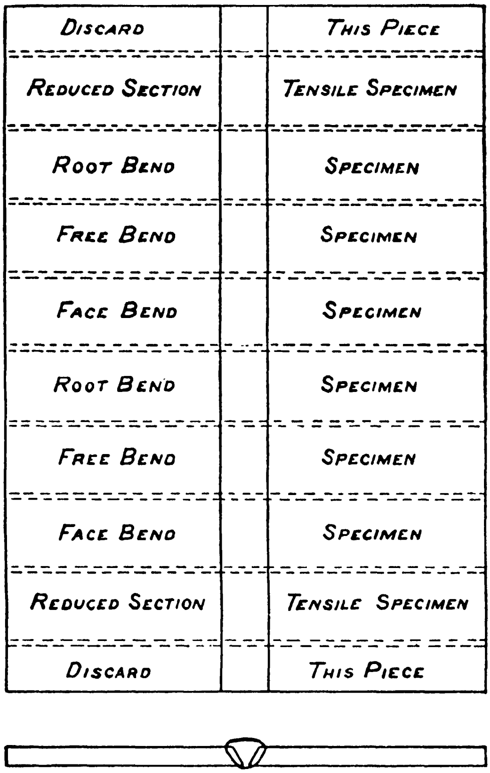


Figure 353. Order of Removal of test specimens from welded test plate (for plate ⅜″ thick)

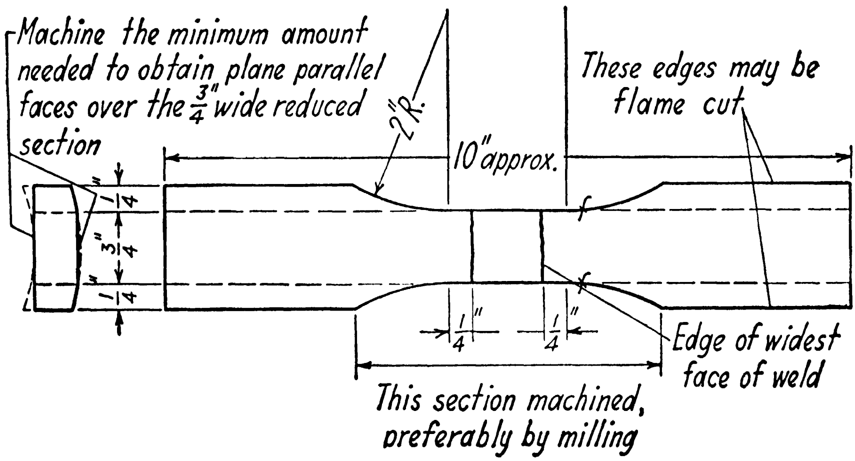


Figure 354. Reduced Section tension specimen (Pipe). The end view is shown on the left

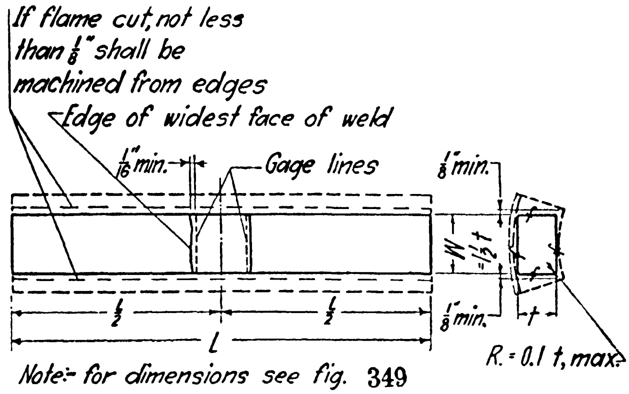
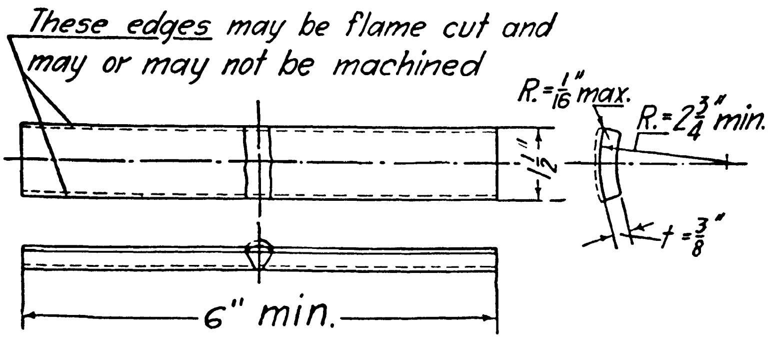


Figure 355. Free-Bend specimen (Pipe). The end view is shown on the right



NOTE: Weld reinforcement and backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above

Figure 356. Face and Post-Bend Specimen (Pipe). The end view is shown on the right

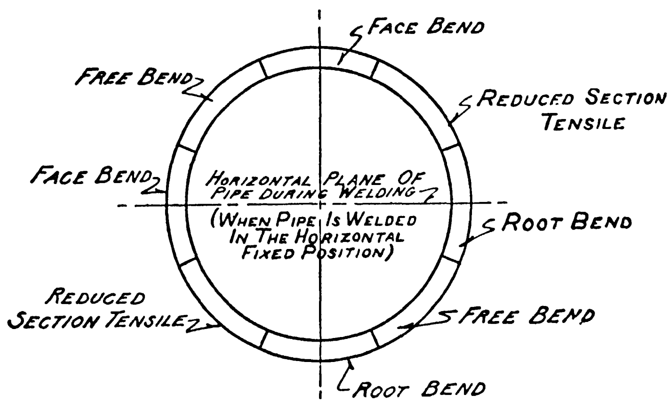


Figure 357. Order of Removal of test specimens from Welded Pipe (for pipe ⅜" thick)

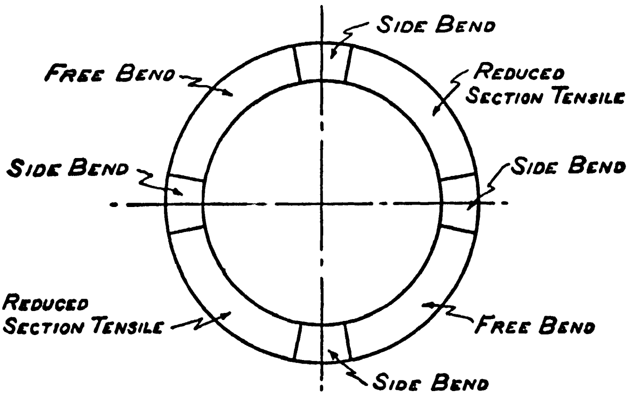
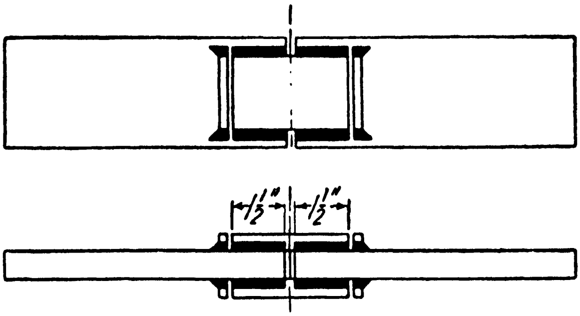


Figure 358. Order of Removal of test specimens from Welded Pipe (for pipe over ¾″ thick)



Note—for other dimensions see Fig. 345

Figure 359. Longitudinal Fillet-Weld Shearing specimen after machining

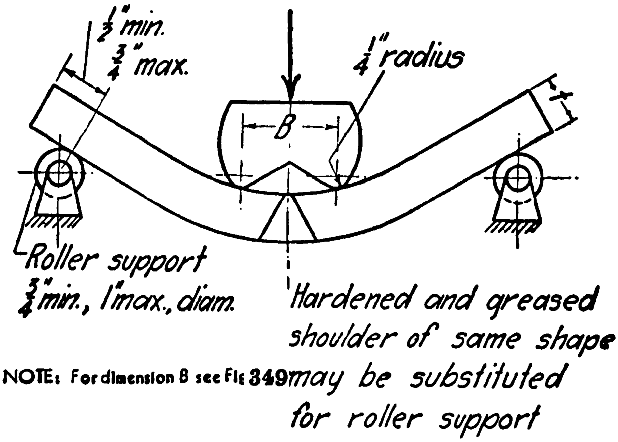


Figure 360. Initial Bend for Free-Bend Specimen

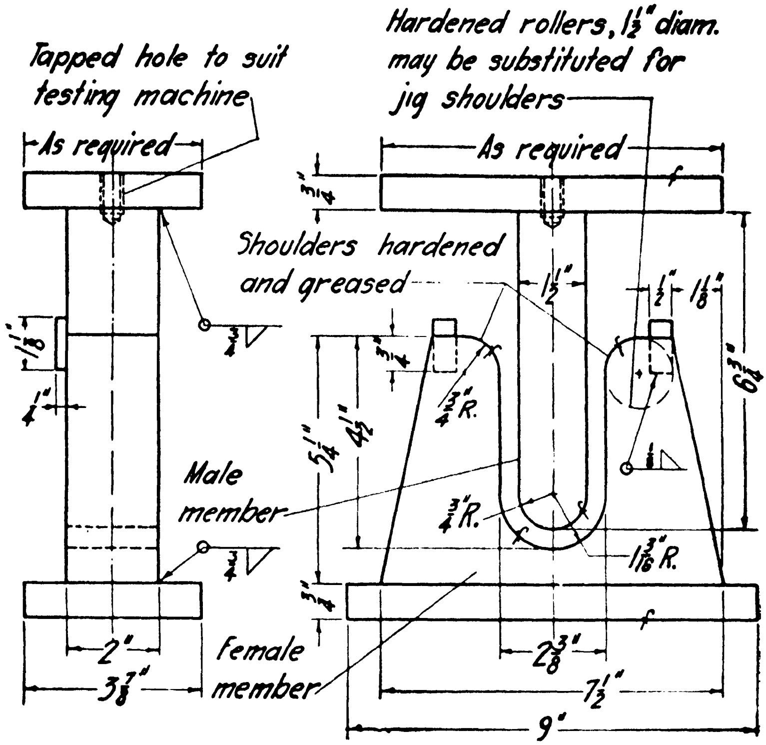


Figure 361. Guided Bend Test Figure

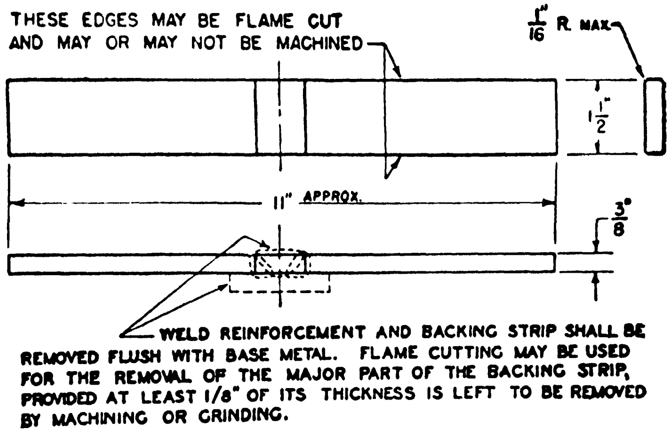
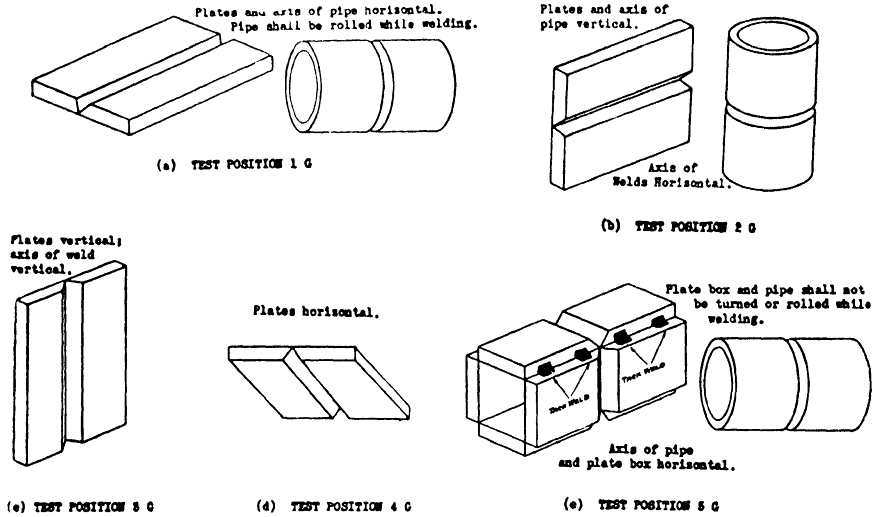


Figure 362. Fillet-Weld-Soundness Test Specimen



NOTE· For procedure qualification the type of groove shall comply with the Procedure Specification, for operator qualification the shape of the groove and backing strip shall be as shown.

Figure 363. Position of Pipe or Test plates for Groove Welds

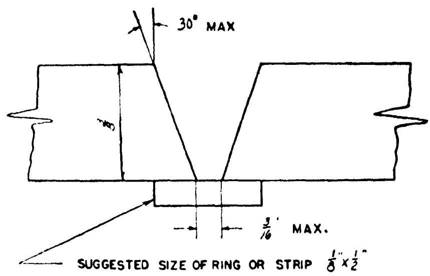


Figure 364. Butt joint for operator Qualification, for Plate or Pipe ⅜" thick

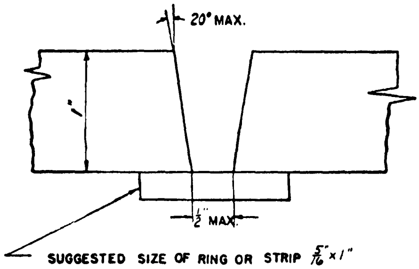


Figure 365. Butt joint for operation Qualification, for Plate or Pipe 1" thick

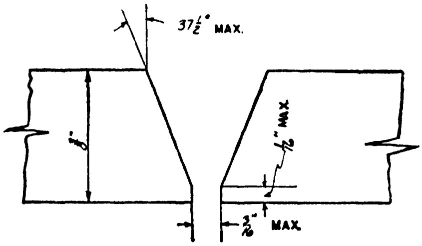


Figure 366. Alternate Butt Joint for Operation Qualification, for plate ⅜" thick, may be used for oxy-acetylene process only

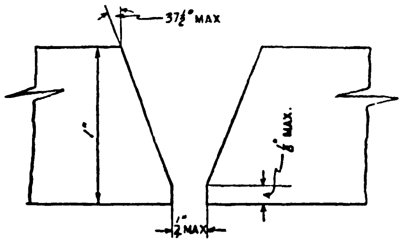


Figure 367. Alternate Butt Joint for Operation Qualification, for plate 1" thick, may be used for oxy-acetylene process only

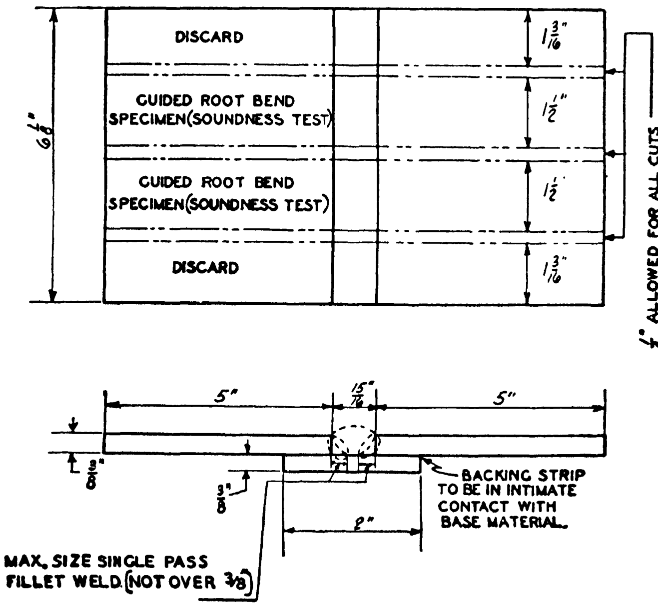


Figure 368. Test weld for soundness tests for operator Qualification

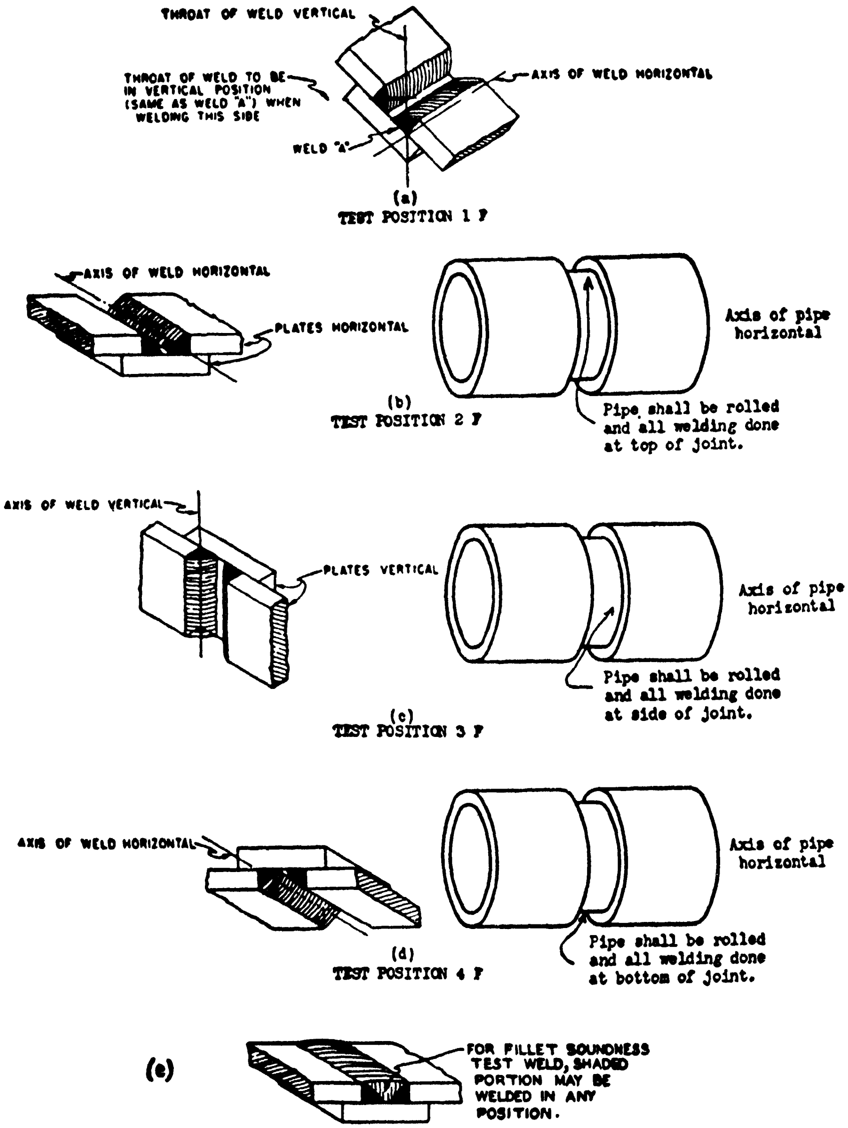


Figure 369. Positions for test plates or pipe for Fillet Welds for Operator Qualification

APPENDIX

RECOMMENDED FORMS OF PROCEDURE SPECIFICATIONS

I. Carbon Arc Welding Process:

PROCEDURE SPECIFICATION FOR CARBON ARC WELDING OF

(State Class of Object to be Welded)

Specification No.............

Date ....

Process: The welding shall be done by the Carbon Arc Process.

Base Metal: The base material shall conform to the Specifications for (insert here references to standard A. S. T. M. or other Code designations, or give the chemical analysis and physical properties).

Filler Metal: The filler metal shall conform to Classification Number ——— of the American Welding Society's Specification for (insert here the title of the desired specification).

Position: The welding shall be done in the (give the position or positions in which the welding will be done. See Article 104).

Preparation of Base Material: The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether sheared, machined, ground, gas cut, etc.), as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketches referred to should show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or base metal thicknesses to be welded.)

Size of Carbon or Graphite Electrodes: The range in size of carbon or graphite electrodes shall be as shown on the attached sketch. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of electrode sizes for each thickness of material.)

Nature of Electric Current: The current used shall be (state whether direct or alternating and if alternating give the frequency). The base material shall be on the (state whether negative or positive) side of the line.

Method of Welding: The method of welding used shall be that known as (describe whether "backhand" or "forehand").

Current Characteristics: The approximate voltage and amperage during welding shall be as shown on the attached sketches. (The sketches referred to may be the same as those under "Preparation of Base Material" or under "Number of Layers and Passes of Welding.")

Size of Welding Rod: The size of rod used for the various base material thicknesses shall be as shown on the attached sketches. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set.)

Number of Layers and Passes of Welding: The number of layers and passes of welding used shall be as shown on the attached sketches. (The sketches

referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of thicknesses for which one, two or more layers are used.)

Cleaning: All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead.

Defects: Any cracks or blow-holes that appear on the surface of any bead of welding shall be removed by chipping, grinding or gas gouging before depositing the next successive bead of welding.

Peening: (If peening is to be used, it shall be incorporated as part of the Specifications, a description being given of the degree of peening to be done.)

Treatment of Under Side of Welding Groove: (The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

II. Metal Arc Welding Process:

PROCEDURE SPECIFICATION FOR METAL ARC WELDING OF

(State Class of Object to be Welded)

Specification No.............

Date.......................

Process: The welding shall be done by the Metal Arc Process.

Base Metal: The base material shall conform to the Specifications for (insert here references to standard A. S. T. M. or other Code designations, or give the chemical analysis and physical properties).

Filler Metal: The filler metal shall conform to Classification Number ——— of the American Welding Society's Specification for (insert here the title of the desired specification).

Position: The welding shall be done in the (give the position or positions in which the welding will be done. See Article 104.)

Preparation of Base Material: The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether sheared, machined, ground, gas cut, etc.), as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketches referred to should show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or base metal thicknesses to be welded.)

Nature of Electric Current: The current used shall be (state whether direct or alternating and if alternating give the frequency). The base material shall be on the (state whether negative or positive) side of the line.

Welding Technique: The welding technique, electrode sizes, and mean voltages and currents for each electrode shall be substantially as shown on the attached sketches. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be separate sketches. They should show for the minimum thickness and for several intermediate thicknesses of base material, the welding technique to be used, whether weaving or beading, the number of layers or passes and diameter of electrode with the mean voltage and current for each layer or pass, and in the case of vertical welds, the progression of each pass, whether upward or downward.)

NOTE: Since, in the welding of many materials in the flat position and particularly for the ordinary mild steels, the proper welding "heat" can be readily determined by the appearance of the individual beads of welding, the use of a "Standard Appearance Weld" may be desirable for the flat position. Such a weld should be made in the maximum thickness that will be used in construction, except that the maximum thickness of the Standard Appearance Weld need not exceed ¾ in., and should show approximately 2 in. of the surface of each layer and a cross section through the weld at each layer, where such cross section is found necessary to produce a clearly understandable photograph. When a Standard Appearance Weld is used the following paragraph should be used in lieu of specifying current and voltage values.

Appearance of Welding Layers: The welding current and manner of depositing the weld metal shall be such that the layers of welding as deposited shall have the appearance shown on the photographs attached hereto. There shall be practically no undercutting on the side walls of the welding groove or the adjoining base material.

Cleaning: All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead.

Defects: Any cracks or blow-holes that appear on the surface of any bead of welding shall be removed by chipping, grinding or gas gouging before depositing the next successive bead of welding.

Peening: (If peening is to be used, it shall be incorporated as part of the Specifications, a description being given of the degree of peening to be done.)

Treatment of Under Side of Welding Groove: (The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

III. Oxyacetylene Welding Process:

PROCEDURE SPECIFICATION FOR OXYACETYLENE WELDING OF

(State Class of Object to be Welded)

Specification No. . . . .

Date . . . .

Process: The welding shall be done by the Oxyacetylene Process.

Base Metal: The base material shall conform to the Specifications for (insert here references to standard A. S. T. M. or other Code designations, or give the chemical analysis and physical properties).

Filler Metal: The filler metal shall conform to Classification Number ——— of the American Welding Society's Specification for (insert here the title of the desired specification).

Position: The welding shall be done in the (give the position or positions in which the welding will be done. See Article 104.)

Preparation of Base Material: The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether sheared, machined, ground, gas cut, etc.), as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketches referred to should show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or base metal thicknesses to be welded.)

Size of Welding Tip: The range in size of welding tips used shall be as shown on the attached sketch. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of tip sizes for each thickness of material.)

Nature of Flame: The flame used for welding shall be (state whether a neutral flame or one with slight excess of acetylene is to be used).

Method of Welding: The method of welding used shall be that known as (describe whether "backhand" or "forehand").

Size of Welding Rod: The size of rod used for the various base material thicknesses shall be as shown on the attached sketch. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set.)

Number of Layers of Welding: The number of layers of welding used shall be as shown on the attached sketches. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of thicknesses for which one, two or more layers are used.)

Cleaning: All slag or flux remaining on any layer of welding shall be removed before laying down the next successive layer.

Defects: Any cracks or blow-holes that appear on the surface of any layer of welding shall be removed by chipping, grinding, or gas gouging before depositing the next successive bead of welding.

Peening: (If peening is to be used, it shall be incorporated as part of the Specifications, a description being given of the degree of peening to be done.)

Treatment of Under Side of Welding Groove: (The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

388. Color Codes for Marking Metals and Alloys

(Courtesy of: Victor Equipment Company)

STEELS FROM BUREAU OF STANDARDS' SIMPLIFIED PRACTICE RECOMMENDATION R166-37

S.A.E. Number	Code Color	S.A.E. Number	Code Color
	CARBON STEELS		NICKEL STEELS
1010	White	2015	Red and brown
1015	White	2115	Red and bronze
X1015	White	2315	Red and blue
1020	Brown	2320	Red and blue
X1020	Brown	2330	Red and white
1025	Red	2335	Red and white
X1025	Red	2340	Red and green
1030	Blue	2345	Red and green
1035	Blue	2350	Red and aluminum
1040	Green	2515	Red and black
X1040	Green		MOLYBDENUM STEELS
1045	Orange	4130	Green and white
X1045	Orange	X4130	Green and bronze
1050	Bronze	4135	Green and yellow
1095	Aluminum	4140	Green and brown
	FREE CUTTING STEELS	4150	Green and brown
1112	Yellow	4340	Green and aluminum
X1112	Yellow	4345	Green and aluminum
1120	Yellow and brown	4615	Green and black
X1314	Yellow and blue	4620	Green and black
X1315	Yellow and red	4640	Green and pink
X1335	Yellow and black	4815	Green and purple

388. Continued.

S.A.E. Number	Code Color	S.A.E. Number	Code Color
X1340	Yellow and black	4820	Green and purple
	MANGANESE STEELS		CHROMIUM STEELS
T1330	Orange and green	5120	Black
T1335	Orange and green	5140	Black and white
T1340	Orange and green	5150	Black and white
T1345	Orange and red	52100	Black and brown
T1350	Orange and red		CHROMIUM-VANADIUM STEELS
	NICKEL-CHROMIUM STEELS	6115	White and brown
3115	Blue and black	6120	White and brown
3120	Blue and black	6125	White and aluminum
3125	Pink	6130	White and yellow
3130	Blue and green	6135	White and yellow
3135	Blue and green	6140	White and bronze
3140	Blue and white	6145	White and orange
X3140	Blue and white	6150	White and orange
3145	Blue and white	6195	White and purple
3150	Blue and brown		TUNGSTEN STEELS
3215	Blue and purple	71360	Brown and orange
3220	Blue and purple	71660	Brown and bronze
3230	Blue and purple	7260	Brown and aluminum
3240	Blue and aluminum		SILICON-MANGANESE STEELS
3245	Blue and aluminum	9255	Bronze and aluminum
3250	Blue and bronze	9260	Bronze and aluminum
3312	Orange and black		
3325	Orange and black		
3335	Blue and orange		
3340	Blue and orange		
3415	Blue and pink		
3435	Orange and aluminum		
3450	Black and bronze		

NON-FERROUS METALS FROM FEDERAL STANDARD STOCK CATALOGUE

(Courtesy of: Victor Equipment Company)

Metal	Grade	Specifications			Markings	
		Federal	Navy	A.S.T.M.	Background	Stripe
ALCLAD					Lead & tan	Black
ALUMINUM	B	QQ-A-451	46-A-2		Lead & tan	Brown
soft	A		46-A-3		Lead & tan	White
half hard	B		46-A-3		Lead & tan	Green
three-quarters	C		46-A-3		Lead & tan	Yellow
hard	D		46-A-3		Lead & tan	Red
ALUMINUM ALLOY, soft			46-A-4		Lead & red	None
half hard	B		47-A-4		Lead & red	Blue
hard	D		47-A-4		Lead & red	Brown
heat treated			47-A-3		Lead & red	Black
heat treated and rolled			47-A-3		Lead & red	White
Navy alloy A-2					Lead & white	None
Navy alloy A-2, heat treated					Lead & white	Black
Navy alloy No. 2, annealed					Lead & white	Brown
Navy alloy No. 2, annealed, heat treated					Lead & white	Green
Navy alloy No. 4, soft					Lead & yellow	Blue
BRASS			46-B-26		Brown & green	Black
Commercial, type 1	A	QQ-B-611		B15-18	Brown & green	Blue
Commercial, type 1	B	QQ-B-611		B16-18	Brown & green	Lead
Commercial, type 1	C	QQ-B-611			Brown & green	Tan
Commercial, type 2	B	QQ-B-611	47-B-2		Brown & green	Red
Commercial, type 2	C	QQ-B-611			Brown & green	White
Naval, rolled			46-B-6		Brown & green	Yellow
BRONZE	1	QQ-B-701	46-B-25		Brown & tan	Black
	2	QQ-B-701	46-B-25		Brown & tan	Blue
	3	QQ-B-701	46-B-25		Brown & tan	Green
	4	QQ-B-701	46-B-25		Brown & tan	Lead
	5	QQ-B-701	46-B-25		Brown & tan	Red
	6	QQ-B-701	46-B-25		Brown & tan	White
Aluminum			46-B-19		Brown & white	Black
Journal			46-B-9		Brown & white	Blue
Manganese		QQ-B-721	46-B-16	B7-27	Brown & white	Green
Muntz Metal					Brown & white	Lead
Phosphor			46-B-14		Brown & white	Tan
Rivet					Brown & white	Red
Special					Brown & white	Yellow

Non-Ferrous Metal—continued

Metal	Grade	Specifications			Markings	
		Federal	Navy	A.S.T.M.	Background	Stripe
COPPER, hard drawn		QQ-C-501	47-C-2		Red & white	Black
Soft drawn		QQ-C-501	47-C-2		Red & white	Blue
Phosphor	A	QQ-C-571	46-C-3		Red & yellow	Black
Silicon		QQ-C-581	46-C-2	B53-27	Red & yellow	Brown
Nickel		QQ-C-541	46-M-7		Red & yellow	Green
NICKEL	A	QQ-N-301	46-N-2	B39-22	Green & lead	Black
	B	QQ-N-301	46-N-2	B39-22	Green & lead	Blue
MANGANESE-NICKEL			46-N-3		Green & tan	Black
NICKEL-SILVER	A	QQ-N-321	46-S-3		Green & tan	Lead
TIN, phosphor		QQ-T-351	46-T-2	B51-27	Green & yellow	Black
ZINC	A	QQ-Z-351	46-Z-1		Green & white	Black
	B	QQ-Z-351	46-Z-1		Green & white	Blue
	C	QQ-Z-351	46-Z-1		Green & white	Brown
	D	QQ-Z-351	46-Z-1		Green & white	Lead
	E	QQ-Z-351	46-Z-1		Green & white	Tan

389. FLAME CHARACTERISTICS: HEAT UNITS AND FLAME TEMPERATURE OF VARIOUS FUEL GASES

Gas	B.T.U. Per Cu. Ft.	Flame Temperature With Pure Oxygen
		F.°
Acetylene	1650	5600
Hydrogen	360	4600
Carbo-Hydrogen	480	4560
City Gas	600	4400

INDEX

INDEX

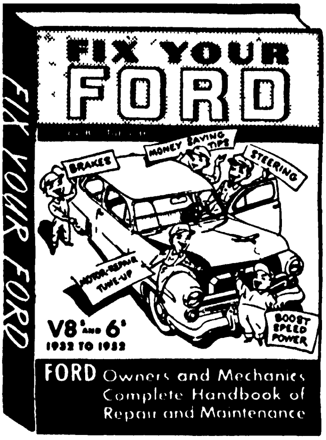
D

Q

R

X

Z



BOOKS

THAT TELL YOU AND SHOW YOU HOW

FIX YOUR FORD. By Bill Toboldt, Editor, Motor Service Magazine.
This brand new book covers servicing and repairing of Ford V-8's and 6's from 1932 up to and including the 1952 models; tells how models differ, what is unusual, how to increase speed and power, what repair shortcuts and kinks can be used to save money. FIX YOUR FORD, which is based on successful experience and know-how of the country's top Ford service men, is of value not only to the car owner who wants to repair his own Ford, but also to the experienced mechanic who wants to do a better job in less time. Price $2.50.

DYKE'S AUTO ENCYCLOPEDIA (World's most Famous Auto Book.) New 22nd Edition now available.
"Dyke's" is a complete course of instruction in automotive mechanics, with special emphasis on elementary fundamental principles, trouble shooting, testing, repairing, with every operation explained in detail. It tells HOW to do things, along with the WHY . . . is an indispensable aid in servicing of all cars no matter when and where made. 1492 pages, over 4600 illustrations. Price $7.50.

AUTOMATIC TRANSMISSIONS SIMPLIFIED. By Jud Purvis, Technical Editor of Motor Service Magazine.
Learn all about: Fordomatic, Merc-O-Matic, Hydra-Matic, Simplimatic, Drive-Master and all other transmissions. AUTOMATIC TRANSMISSIONS SIMPLIFIED, a practical guide to handling all kinds of transmission jobs, transposes engineering terms into "ham and eggs" language, carefully explains transmission fundamentals, tells and shows you how transmissions are constructed, how they operate and how to service them. For everyone who is in any way interested in automatic transmissions. Price $4.00.

DYKE'S CARBURETOR BOOK. By A. L. Dyke.
Use this book to become a specialist in auto engine tune-up. Covers carburetors, ignition, fuel pumps, etc. Price $3.50.

AUTO BODY AND FENDER REPAIRS. By C. E. Packer.
Here is a book covering every phase of auto body and fender repairs including frame straightening. It gives information on the use of tools and equipment, approved methods, describes materials and shows you how to do a professional job, operate a shop, etc. Even in small towns body and fender repair shops can be successfully and profitably operated. Price $3.50.

List of GOODHEART-WILLCOX Books

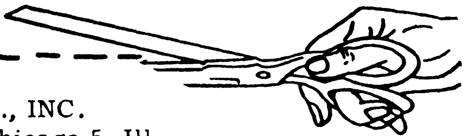
FARM MECHANICS POWER TOOL MANUAL. By Floyd Mix and J. C. Moore. This new Power Tool Manual tells in easy-to-understand language and shows in crystal-clear drawings and photos, how to use 21 power tools Efficiently and Safely. Information given is applicable to both farm shop and home (hobby) workshop tools. Special emphasis is placed on SAFETY. Tools covered: Circular Saw, Radial Arm Saw, Portable Electric Saw, Portable Electric Drill, Drill Press, Power Grinder, Jointer, Thickness Planer, Band Saw, Chain Saw, Portable Belt Sander, Metal Working Lathe, Power Hack Saw, Flexible Shaft, Farm Arc Welders, Oxy-Acetylene Flame, Air Compressor, Paint Sprayer, Wood Lathe, Jig Saw, Shaper. Price $3.50.

MODERN WELDING PRACTICE. By A. D. Althouse and C. H. Turnquist An up-to-date encyclopedia of welding information. Covers all types of gas, electric welding, heat treating and metal cutting including submerged arc and inert gas welding, arc-oxygen cutting, underwater cutting and welding, stud welding, sprayed hard surfacing, welding tool and die steel, powder and flux cutting of high alloy steels. Price $5.00.

HOUSE WIRING. By Wolber and Rose.
Instruction in all phases of house wiring. Price $3.00.

A. C. POWER WIRING. By Wolber and Rose. Price $4.00.

D. C. POWER WIRING. By Wolber and rose. Price $4.00.



GOODHEART-WILLCOX CO., INC.
1321 South Michigan Ave., Chicago 5, Ill.

Please send books listed below, on your
MONEY-BACK GUARANTEE:

Quantity	Title	Price
[illegible]	Fed. [illegible]	5½ N.P. [illegible]
		[illegible]

Total Amount Enclosed $________

Name ______ [illegible] ______

Address ______ [illegible] ______ State ______ [illegible]

Printed in U. S. A.